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TABLES OF DIELECTRIC MATERIALS, VOL V



A. VON HIPPEL W. B. WESTPHAL

LABORATORY FOR INSULATION RESEARCH MASSACHUSETTS INSTITUTE OF TECHNOLOGY CAMBRIDGE MA

APRIL 1957

FINAL REPORT

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MATERIALS DIRECTORATE
WRIGHT LABORATORY
AIR FORCE SYSTEMS COMMAND
WRIGHT PATTERSON AFB OH 45433-7734

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ERRATA

Tables of Dielectric Materials, Vol. V

Page viii, line 6, for "0.1" read " < 0.1."

- " x, line 8, for "0.005" read " < 0.005"; for "l" read " > 1"; line 10, for "0.002" read " < 0.002."
- " 2, line 3 from bot., for "1.3," "1.7," "4.8" read "13," "1.3," "1.7."
- " 4, line 11, for "0.004" read "0.044"; line 13, delete "268" and "21.4."
- " 5, lines 6 and 7, raise to correspond with "Corning 7910."
- " 7, line 3 from bot., for ".3.68" read "3.68."
- " 8, line 4, for "-275" read "275"; line 5, for "33.27" read "3.27."
- " 11, line 6, for "--31" read "31."
- " 13, line 3, for "to film" read " \(\perp \) to film"; lines 9 and 11 from bottom of Table, change single to double asterisks.
- " 14, line 8, for "4.84" read "3.84."
- " 161 and 165, "Note," for " K_m " read " κ_m^* ."
- " 174, line 2, delete " "Fe."
- " 175, line 2, for "Cerqmivs" read "Ceramics."
- " 245, line 9, first column, for "Iv-58" read "IV-58."
- " 247, line 19, second column, for "159-175" read "159-176."
- "249, line 6 from bot., first column, for "133-139, 142-158, 177-180" read "133-136, 138,139,142-158, 177, 179, 180"; second column, line 2, for "V-140, 141" read "V-137,140,141"; line 3, for "176,181,182" read "176,178,181,182."

Laboratory for Insulation Research
Massachusetts Institute of Technology

In addition to the printed errata the following errors have come to our attention:

Page 6, Boron nitride, add these tan 8's:

f	ten 8
1x10 ²	10.3
1×10 ³	6.5
lx10 ⁴	4.2
1x10 ⁵	3
lx10 ⁶	2.0
lxlo ⁷	1.4
lx10 ⁸	0.92

Page 39, $\tan \delta$ at $i = 10^{10}$ should be:

TOC	tan 8
26	0.00026
116	0.00029
506	0.00054
302	0.00044
412	0.00058
457	0.00069
499	0.00080

Page 52, "Wesgo" Al-300:

$$f = 9.5 \times 10^9$$
 instead of $f = 9.5 \times 10^{10}$; tan 8 scale should read:

0.0006

A

0.0002

TABLES OF DIELECTRIC MATERIALS VOLUME V

Laboratory for Insulation Research

Massachusetts Institute of Technology

Cambridge, Massachusetts

The work reported in this document was made possible through support extended to the Massachusetts Institute of Technology, Laboratory for Insulation Research, jointly by the Navy Department (Office of Naval Research), the Army Signal Corps, the Air Force (Air Matériel Command), and the Ordnance Materials Research Office under ONR Contract Nonr-1841(10), NR-017-421. Reproduction of this article in whole or in part is permitted for any purpose of the United States Government.

Table of Contents

																Page
Int	rod	ucti	on		•	•	•			•			•	•	•	v
Di	elec	tric	Par	ame	eters	;	•		•	•			•	. •	•	viii
Μe	easu	ren	nents	and	Acc	cura	acy		•				•	•	•	x
I.	Tai	bula	ted	Diel	ectri	c I) ata	at 1	Roor	n T	emp	pera	ture		•	l
	Α.	So	lids,	ino	rgan	ic	•	•	•	•			•		•	1
		1.	Cry	stal	s		•	•	•	•		•	•			1
		2.	Cer	ami	cs	•	•		•		•	•				1
			a.	Alu	mina	ıs	•		•	•		•				1
			b.	Fer	rite	s	•		•			•			•	4
			c.	Stea	atite		•	•	•	•	•		•	•	•	4
			d.	Wol	llast	oni	tes				•	•			•	4
			e.	Zir	con		•		•	•	•	•			•	5
		3.	Gla	sses	s, in	clu	ding	dev	vitri	fied	l gla	ısse	s	•		5
		4.	Mis	cell	aneo	us	inoı	gan	ics		•	•		•	•	6
	в.	So.	lids,	org	ganic		. •	•	•	•	•		•	•	•	8
		1.	Pla		s (in lami:			g pla	stic	s w	ith.	fille	rs,		•	8
			a.	Phe	noli	c r	esin	s	•	•	•	•			•	8
			b.	Mel	lami	ne-	forr	nalo	lehy	de	•	•	•			8
			с.	Cel	lulos	se d	leri	vati	ves	•	•	•	•	•		9
			d.	Sili	cone	re	sins	5	•	•	•	•	•	•	•	9
			ε.	Pol	yvin	yl r	esi	ns		0	•	•	•	•		10
				(1)	Poly	eth:	nylei	ne	•	•	•	. •				10
				(2)	Pol	yviı	nyl (chlo	ride	-ac	etat	te	•	•		10
				(3)	Pol	ych	lord	trif	luor	oet	hyle	ene	•	•	•	10
				(4)	Dol-	utet	traf	lu 0 ==	oath	371 G	n a					10

Table of Contents (cont.)

														Page
			(5)	Polya	cryl	ate		•		•	•	•		10
			(6)	Polys	tyre	ne		•		•	•	•	•	10
			(7)	Misce	ellan	eou	s po	lyst	yre	nes	•	•	•	11
			(8)	Styre	ne c	opol	yme	ers,	cro	oss-	link	ed		11
		f.	Poly	yester	s		•	•	•	•		•	•	12
		g.	Epo	xy res	sins	•	•	•	•		•	•		14
		h.	Mis	cellan	.eous	s pla	astic	cs		•	•	•		16
		2. Wa	axes	•	•	•	•	•	•			•	•	16
		3. Mi	iscell	laneou	sor	gani	.cs	•						17
	c.	Liquid	ls .			•		•	•					18
		1. Inc	orgar	nic .	•	•	•	•	•				•	18
		2. Or	gani	c .	•	•	•	•	•			•	•	18
		a.	Ali	phatic		•	•	•	•		•			18
		b.	Arc	matic	•	•	•	•			•		•	19
		с.	Pet	roleun	n oil	Ĺ	•	•	•		•		•	19
		d.	Sili	cones				•	•				•	20
	D.	Gases				•	•	•	•		•		•	20
II.	Supp	plemen	t											
	Α.	Mater		measu: ection							on •		•	21
	в.	Dielec		consta densit							e •	•	•	23
III.	Data	at Fix							tion					
		of T	emp	eratur	e	•	•	•	•	•	•	•	•	26
	Α.	Solids	, ino	rganic	•	•	•	•	•	•	•	•	•	26
		1. Cr	ystal	ls .	•	•	•	•	•	•	•	•	•	26
		2. Ce	rami	ics	•	•	•	•	•	•	•	•	•	30

Table of Contents (cont.)

		Pa	ge
		a. Aluminas	0
		b. Beryllias 57	2
		c. Ferrites	4
		d. Steatites	5
		e. Wollastonite	3
		f. Zircons	7
		3. Glasses 62	2
		4. Miscellaneous inorganics	1
	В.	Plastics)
		1. Phenolics)
		2. Melamine-formaldehyde 88	3
		3. Polyamide resin)
		4. Cellulose derivatives)
		5. Silicone resins	3
		6. Polychlorotrifluoroethylene 102	2
		7. Polytetrafluoroethylene 104	ŀ
		8. Styrene copolymers	5
		9. Polyesters)
		lo. Alkyd resins	3 ,
		11. Epoxy resins	ļ
	C.	Elastomers	•
	D.	Liquids)
IV.	Fer	omagnetic Dielectrics	•
	Α.	Low field strength data at fixed temperatures as a function of frequency	ı
	71	1. Nickel ferrite, single crystals	

Table of Contents (cont.)

				Page
2	. Cobalt ferrite, high density ceramic .	•	•	136
3	. Lithium-nickel ferrite ceramic	•	•	137
4	. Magnesium ferrite, high density ceramic	•	•	138
5	. Magnesium-manganese ferrite ceramics	•	•	139
6	. Magnesium-manganese-zinc ferrite ceramic			141
7	. Nickel ferrite, high density ceramic .	•	•	142
8	. Nickel-zinc ferrites, high density ceram	ics		144
9	. Zinc ferrite, high density ceramic .	•	•	158
10	. Commercial ferrite ceramics	•	•	159
в. н	lysteresis loops and saturation magnetization	n	•	177
1	. Cobalt ferrite, high density ceramic .	•		177
2	. Lithium-nickel ferrite ceramic	•		178
3	. Magnesium ferrite, high density ceramic	: .	•	179
4	. Magnesium-manganese ferrite ceramics		•	180
5	. Magnesium-manganese-zinc ferrite, cer	ami	С	182
6	. Nickel ferrite, high density ceramic .	•	•	183
7	. Nickel-zinc ferrite, high density cerami	cs	•	184
8	. Commercial ferrite ceramics	•		191
9	. Magnetic plastic mixture	•		205
V. Atten	uator Characteristics (attenuation, phase			
	shift, and intrinsic impedance)	•	•	206
A. F	Cerrites	•	•	206
в. с	Conducting ceramics	•	•	234
c. c	Conducting plastics	•	•	235
D. C	Carbon-plastic mixtures	•	•	237
E. N	Magnetic plastic mixtures	•		242
Company 1	Index	•		245
Materials	Index		•	253

Tables of Dielectric Materials

Volume V

Laboratory for Insulation Research

Massachusetts Institute of Technology

Cambridge, Massachusetts

During World War II the Laboratory for Insulation Research assumed, in addition to other tasks, the responsibility of acting as a clearing house for dielectric information. It developed measurement techniques over wide ranges of frequency and temperature, provided data on materials of strategic importance and summarized the results in the "Tables of Dielectric Materials."

Volumes I and II were issued during the war. The termination of hostilities, however, did not end our obligation. Government and Industry relied on these data, and the idea had become entrenched that materials of general interest could be measured in our laboratory free of charge in return for background information required for the defense effort. Volume III was issued in 1948, and our clearing house activity stepped up when the outbreak of the Korean war emphasized the precariousness of the political situation. Volume IV, released in January 1953, summarized in expanded measurements all materials of importance at that time and was made generally available as Appendix to the book "Dielectric Materials and Applications" (Technology Press and John Wiley and Sons, New York, 1954). In the interim periods, the accumulating information aided Government agencies and industrial laboratories in the selection and development of dielectrics under Government contracts.

Since 1953 the missile age has arrived with its demands for hightemperature dielectrics. At the same time the concepts of "Molecular Engineering, "on which the Laboratory for Insulation Research was founded, are rapidly becoming public property: dielectrics are being made to order for an increasing number of new devices. These trends are reflected in Volume V of the "Tables" by extension to high-temperatures (Sec. III), ferromagnetics (Sec. IV) and attenuator characteristics (Sec. V).

Like its predecessors, Volume V is a storage bin of <u>practical</u> information, ill-adapted for theoretical analysis. Here are radome materials and glass cloth; jet fuel and compressed gases; Scotch tape, Kraft paper and Sauereisen cement, to mention only some of the more outlandish representatives. Here is demonstrated that impure raw materials cause inferior high-temperature performance and that overheating produces rapid degradation. There are also examples of beneficial action of heating in driving out detrimental moisture and volatile compounds. Trends are revealed for the development of better materials, and faulty manufacturing practices are exposed for remedial action. Our task here is an unbiased presentation of data, which leaves the users of the "Tables" free to draw their own conclusions.

A true dielectric analysis of materials requires a different approach: accurately defined materials; controlled variation of composition and structure; careful investigation of the influence of manufacturing parameters; and a comparison of the properties of multicrystalline materials with those of single crystals. This arduous task has been started in our laboratory for ferromagnetic semiconductors by a careful ceramics study of square-loop materials (G. Economos, Tech. Rep. 78, May, 1954; J. Amer. Ceram. Soc., July through November, 1955); in an extensive broad-band investigation of ferrites from d.c. to the ultraviolet (A. von Hippel, W.B. Westphal and P.A. Miles, "Dielectric Spectroscopy of Ferromagnetic Semiconductors," Tech. Rep. 97, July, 1955, revised for Revs. Mod. Phys., July, 1957);

and by a detailed analysis of a special type of relaxation spectrum identified in ferrites (D. J. Epstein, "Domain-Wall Relaxation in Ferrites," Papers presented at the Conference on Magnetism and Magnetic Materials, Boston, Mass., Oct. 16-18, 1956, Amer. Inst. Elec. Engrs. T-91, 1957, p. 493).

The development of "Dielectric Spectroscopy" into a powerful tool of nondestructive analysis for the whole field of "Molecular Science and Engineering" should receive top priority in the use of our resources from now on. We intend therefore to terminate the service "Tables of Dielectric Materials" by the end of this year; a Volume VI will summarize ferroelectric and residual data. We hope that some independent and unbiased agency will continue this work of evaluating materials and acting as a clearing house for dielectric information.

Our venture was made possible through the ingenuity and indefatigable efforts of Mr. W.B. Westphal, group leader of the dielectric measurements group. Mrs. Barbara Beal East, his able co-worker for several years, measured most of the low field-strength data, supported in recent months by Mrs. Rhoda Yarkin. Mrs. Ann Miller and Frank Bispham gave technical assistance, and Miss Aina Sils and John Mara were of great help in the preparation of the final manuscript. The hysteresis data of Sec. IV were obtained by B. Frakiewicz with F. Bispham and under the general direction of Prof. D.J. Epstein, group leader of the ferromagnetics group.

The Laboratory for Insulation Research has operated under the joint sponsorship of the Navy Department (Office of Naval Research), the Army Signal Corps, the Air Force (Air Matériel Command), and the Ordnance Materials Research Office for many years in an atmosphere of mutual trust and understanding; we gratefully acknowledge this support.

Dielectric Parameters

- 1. ϵ'/ϵ_0 , the dielectric constant or permittivity relative to vacuum, also designated in the literature as K, κ_e , κ' , ϵ , ϵ' , D.C., etc.
- 2. κ' , same as ϵ'/ϵ_0 .
- 3. $\tan \delta$, the dielectric loss tangent or dissipation factor, also designated in the literature as DF, 1/Q, and when losses are low (0.1) as power factor or $\cos \theta$.
- 4. $\tan \delta_d$ or $\tan \delta_e$, same as $\tan \delta$.
- 5. ϵ''/ϵ_0 , the dielectric loss factor relative to vacuum, also designated in the literature as κ'' , ϵ'' . L.F., etc.
- 6. κ^{11} , same as ϵ^{11}/ϵ_0 .
- 7. μ'/μ_0 , the magnetic permeability relative to vacuum, also designated in the literature as μ' , μ_B , μ_0 , κ'_D .
- 8. κ'_{m} , same as μ'/μ_{o} .
- 9. $\tan \delta_m$, the magnetic loss tangent, also designated in the literature as 1/Q.
- 10. μ''/μ_0 , the magnetic loss factor in analogy to the dielectric loss factor; also designated in the literature as μ'' , μ_I , κ''_D .
- 11. $\kappa_{m}^{"}$ same as $\mu^{"}/\mu_{0}$.
- 12. $\kappa''/(\kappa'_m)^2$, a figure of merit for core materials, also designated in the literature as loss factor, $1/\mu'Q$.
- 13. $\tan \delta_t$, the total loss tangent, the sum of $\tan \delta_d$ plus $\tan \delta_m$. Relations between parameters are discussed in Vol. IV. The ferromagnetic sections use the parameter κ''_m instead of $\tan \delta_m$, which becomes clumsy in the frequency region where κ' is close to zero or negative.
- 14. p, the a-c volume resistivity in ohm-cm.
- 15. σ , the a-c volume conductivity in mho/m.
- 16. a, the attenuation constant for propagation in free space in decibel per cm.

- 17. β/β_0 , the phase constant relative to vacuum for propagation in free space.
- 18. |Z|, the magnitude of the intrinsic impedance relative to vacuum for propagation in free space.
- 19. θ , the angle of the intrinsic impedance.

Measurements and Accuracy

The measurements have been made, in general, on only one batch of the material and refer, unless otherwise specified, to samples measured at room temperature (25 to 26° C) and room humidity (30 to 50% R.H.). Due to the wide variety of materials and improvements in techniques, no figures of general validity can be given concerning the accuracy of these measurements. For ϵ'/ϵ_0 , the nominal accuracy is $\pm 2\%$; the accuracy trends are toward $\pm 1\%$ for rigid, low-loss materials (tan $\delta=0.005$) and $\pm 5\%$ for high-loss materials (tan $\delta=1$). For tan δ_d , the nominal accuracy is $\pm 5\%$; for high-loss materials, the error may be $\pm 10\%$. For very low-loss materials (tan $\delta=0.002$), the accuracy is ± 0.0001 when the losses are given as multiples of 0.0001. When the loss is expressed in multiples of 0.00001, the error may be ± 0.00003 . For μ'/μ_0 , the nominal accuracy is $\pm 5\%$, for tan δ_m , $\pm 10\%$.

<u>Field strengths</u>. The linear dielectrics, those normally not field-strength sensitive, were measured at field strengths of approximately 50 volts per cm. in the frequency range 10^2 to 10^8 c/s and at lower field strengths at higher frequencies.

The ferromagnetic materials, unless otherwise noted, were measured at field strengths in their linear region. The values thus measured are the <u>initial</u> permeability.

For laminates, which are in general not isotropic, the direction of the electric field is perpendicular to the plane of the laminate for frequencies in the range 10^2 to $3 \text{x} 10^8$ c/s and parallel for higher frequencies unless otherwise specified.

Some metal-loaded materials have been measured which are slightly diamagnetic, but are not sufficiently homogeneous for precise separation of μ^* and ϵ^* . For these the product of dielectric constant and permeability and the sum of the loss tangents is given.

I. Tabulated Dielectric Data at Room Temperature (25 to 26 °C)

Values of tan δ are multiplied by 10 4 ; frequency given in c/s.	$\frac{9}{10} = \frac{8.6 \times 10^9}{1.4 \times 10^{10}} = \frac{1.4 \times 10^{10}}{1.4 \times 10^{10}} = \frac{2.4 \times 10^{10}}{5 \times 10^{10}}$	9.5						,						-1-				- 4.75	1.1				- 7.73	- 13	- 7.97	- 15	
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o ⁴ ; frec	08 1x10			33														:	1				8	2	1	16	9
d by 16	$\frac{8}{3\times10^{8}}$		v 0	3 11.53	v 0	-				•								!	ì				3 7.8	3 9.2	0.8		
ultiplie	1×108		< 10	11.53	< 10													į.	:				7.8	7.8	8.0	15	τ
are m	$\frac{1 \times 10^7}{1}$		< 10	11.53	< 10													1					7.8	5.8	8.0	11	ŗ
of tan	1×10^{6}		< 10	11.53	< 10													!	1				7.8	7.4	8.0	7.9	1
Values	1×10^{5}	9.53	< 10	11.53	< 10			244	15.					6,62	~	5.97	\ 2	!	-				7.8	9.4	8.0	9.3	7 TT- 1
	$\frac{1\times10^4}{}$		< 10	11.53	< 10	59.	< 40	246	27			5.68	< 23	6.62	^	5.97	4	:	!				7.8	9.5	8.0	18	J. 1000 C.
	$\frac{1\times10^3}{}$		< 2	11.53	%	! ! !	!	247	41	6.82	< 10	1	 	6.62		5.97	9	!	}	31.9	380		7.8	9.8	8.0	22	7:40,50
	$\frac{1\times10^2}{1}$	9.53	< 10	11.53	< 10	1	:	249	62	!!!	!	1		6.62	7	5.97	10		1 1	 	!		7.8	11	8.0	9.7	11 D 9~
	•	€1/€	tan ô	e1/e	tan 6	e1/e	tan ô	ε'/ε ₀	tan 8	€¹/€	tan ô	€¹/€	tan ô	ε'/ε _ο	tan 6	ε'/ε _ο	tan 6	ε¹/ε 0	tan 6	€¹/€	tan 6		د،/د	tan 6	€¹/€ ₀	tan 6	o Data of S Whitehood and III II. 11. 11. 11.
	A. Solids, inorganic 1. Crystals	Aluminum oxide, sapphire	(field L optical axis)	(field optical axis)		Barium titanate, hexagonal		(field optical axis)		Calcium fluoride ^b		Carbon, diamond ^c		Cesium bromide		Cesium iodide		Potassium chloride		Thallium chloride		2. Ceramics a. <u>Aluminas</u>	"AlSiMag" 491 (blue) ^e		"AlSiMag" 513 (pink)		a. Linde Air. h. Lah Ing Bes

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I A 2a. Aluminas (cont.)		1×10^2	1×10^3	$\frac{1 \times 10^4}{1}$	1x10 ⁵	1×10^6	$\frac{1}{1 \times 10}$	$\frac{1\times10^8}{1}$	3x10 ⁸	1x10 ⁹	3×10^{9}	8.6×10^{9}	1.4×10^{10}	$\frac{2.4 \times 10^{10}}{}$	$\frac{5\times10^{10}}{}$
"AlSiMag" 544 ^{a**}	ε ₁ /ε ₀			-	!					!	-	5.80	:	1	5.80
	tan 6		1	1 1 1	-	:	-	1	!	!	;	10	:	-	10
"AlSiMag" 576 ^a	e' /e	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	-	!	7.97			
	tan 8	10	7.5	5.5	4.2	3.4	4.0	6.4	7.9	!	!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!	15			
"AlSiMag" 614 ^a	د، /د	1	!	!	:	-	1 1 1	 	!	-		10.0			
	tan 6	!!!!!	1	!!!	:	:	1 1 1	-	-	;	:	æ			
Coors AL-100 ^b	ε' /ε _,	\$! !	:	-	-	-	-	:	;	-	1	6.47			
	tan 6	!	1 1	:	! ! !	;	1	:	-	}	1	0.9			
Coors AI-200 ^b (1954 sample)	د، <i>ا</i> د	!	!	!	:		!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!	!	† 1	1	:	8.78			
	tan 6	!	!	!	!	!	!	 	!	1	1 1 1	10.4			
Corning JD-40 ^C	e' /e	} ! !	-	:	1	† ! !	 	1	 	! !		; ; ;	8.25		
	tan 8	;	-	!	!	:	!	1	!!!	:	!!!	;	38		
Corning JD-82 ^c	e' /e	-	;	-	!	!	;	!	:	;	;	7.85			- 2
	tan 8	:		! ! !	!	:	;	}	1	!	!	18			2-
Corning JB-123 ^c	e, /e	!	:	!	; ; ;	1	-	1 1 1	!	1 1	1 1	8.02			
	tan 6	1 1	1	!!!	:	:	;	!	:	!	1	20			
Corning WD-131 ^c	e' /e 0	1 1	!	;	!	!	:	-	!		1	7.45			
	tan 6	1	-	!!!		! !	!	1 1	<u> </u>	!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!	1	25			
Corning JB-183 ^c	e¹ /e o	1	;	!	 	1	1	:	!	!	1	1	8.22		
	tan 6	† - -	!	1			1 1	† - - -				:	30		
Diamonite B-890 ^d	€1/€	9.25	9.25	9.25	9.25	9.25	9.25	9.25	9.25	9.23	9.20	9.15			
	tan 6	6	5.4	6.8	2	9	< T	< 1 <	က	5.8	9.1	10			
Diamonite P-3142 ^d	ε''/ε ₀	9.60	09.6	9.60	9.60	9.60	9.60	9.60	9.60	9.53	9.42	9.36			
	tan 6	3.3	1.8	1.4	^ 1	1.5	4.5	4.2	2.5	4.0	0.9	15			
Diamonite P-3459 ^d	$\epsilon^{1}/\epsilon_{0}$	12.8	12.1	10.7	9.43	9.13	9.10	9.10	9.10	9.08	9.05	9.03			
	tan 6	290	577	953	585	120	1.3	1.7	4.8	4.8	8.0	15			
A Amer Land (drug meller) b	2000	[dun]	•	,	•	i	:								

a. Amer. Lava (dry values).
 b. Coors (dry value).
 c. Corning.
 d. Diamonite.
 *Freq. = 9.3x10⁹ c/s.
 *This data superceded on page 21.

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I A 2a. Aluminas (cont.)		1×10^2	$\frac{1 \times 10^2}{1 \times 10^3}$	$\frac{1}{1}$	1×10 ⁵	1×10 ⁶	1×10^7	1×10^8	3x108	$\frac{1\times10^9}{}$	$\frac{3\times10^9}{}$	8.6×10^{9}	1.4×10	2.4×10	5x10 ¹⁰
Diamonite P-3530-40 ^a	€1/€	8,95	8.95			8.95					8.85	8.77			
	tan 6	7.8	5.4	4.6	က	2	œ	80	œ	8.5	10.9	15			
Frenchtown 6096 ^b	€¹/€	!	;	!	1 1	:	1	:	† 1 1	8.17					
	tan 6	F 	!	!	!	;	-	!	!!!	13					
Frenchtown 7873 ^{b, c}	$\epsilon^{i}/\epsilon_{0}$	1	} ! ! ₹	1	! !]] !	; ; 1	!	09.9					
	tan 6	!	 	!		;	:	;	i i !	22					
General Ceramic ADH-211 ^d	ε1/ε ⁰	!	!	!		; ; !	1 1	! ! !	!!!!	1	!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!	7.93			
	tan 6	-	1	1	-	-	- - - -	1	-	:		9.5			
Kearfott High Purity Alumina	e'/e	9.40	9.40	9.40	9.40	! ! !	† • •	! ! !	1 1 1) 	!!!	9.40	9.40	:	9.4
	tan 6	က	< 7	%	< ت	;	1	! ! !	; ; !	! ! !	1 1	1.8	1.5	-	1.7
"Sintox"	€1/€	}	! ! !	1 1	!] 	1	ł !	 	! ! !	1	1	!	9.15	
	tan 6	1		 	1 1 1	1	 	-	1	-			:	16	
Norton 7x ^g	د،/د°	9.65	9.64	9.64	9.64	9.64	9.64	9.64	!	-	1	9.63	9.62		-
(density = 3.86 gm/cc)	tan 6	15.2	15.5	13.2	6	2.7	1.0	1.5	1 1 1	 	i i i	3.2	2.3		3-
Norton 17Z ^g	e1/e0	1	-	!	!!!	;	1 1 1	 	:	:	!!!!	9.20			
	tan 6	:	! ! !	1	!	!	!				1	9.0			
Raytheon 402B	€¹/€ ₀	-	! ! !	!!!	 	!	-	!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!	-	!	 - - -	9.42			
	tan 6	!	!	1	 - - -	1	-	1	1 1 1	-		14			
Stupakoff 1510 ^{i, j}	€1/€	1		1	# 1 1	 	1 1 1	! ! !	† † †	1	1 1	5.72			
•	tan 6	!	1 1 1	!!!!	!!!!	! ! !	!	:	1 1	!	1 1	16^*			
Stupakoff 1540 ^{i, k}	e1/e0	1	!	1 1 1	!	! ! !		-	1 2 1		 	8.97			
. ,	tan 6	; ; ;	!!!!	1 1	 	 	-	;	! !	1 1 1]	5.8			
Stupakoff 1542E ^{1,1}	€1/€ ₀	1 1 1	1	1 1	-	!	-	1	1 1	1	!	9.15			
	tan ô	1	1	! ! !			!	1	1 1	; ;	} ! !	8.9			
Stupakoff 1542P ^{i, m}	€1/€	1 1	:	!	1	!	; ; ;	!	!	;	; ! !	9.34			
	tan ô	. ; . ; ;	 	!!!	}	-	}	-	!	;	-	5.5			
a. Diamonite. b. Frenchtown.	c. Alu	c. Alumina-mulite.		d. Gen. Ceramics.	Cerami		e. Kearfott. f.		Nat'l Res. Corp.	es. Cor	ģ	Iorton, exp	perimental	Norton, experimental materials.	

b. Frenchtown. c. Alumina-mullite. d. Gen. Ceramics. e. Kearfott. f. Nat'l Res. Corp. g. Norton, experimental materials. h. Raytheon. i. Stupakoff. j. 99.8% $A1_20_3$, 10% porosity. k. 95% $A1_20_3$, vitrified. l. 96% $A1_20_3$, extruded. m. 96% $A1_20_3$, pressed.

*At 50% relative humidity.

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	tan 6	1 1	-		-	-			!	}	16			
	و، / و	9.6	9.6	9.6	9.6	9.6	!	9.6	-	:	9.63			
	tan 6	80	2.5	-	-	0.7	!	1.6	; ! !	1 1	5.5			
	د، /د	!	;	:	1 1 1			;	! ! !	-	7.03			
	tan 6	! ! !	-	1	1	!	1	:		:	3.7			
의	I A 2b. Ferrites (Detailed data on other ferrites in ferromagnetics section).	ites in fe	rromag	netics se	ection).	Values	of tan δ	are gi	ven wit	hout mul	Values of $\tan \delta$ are given without multiplying factor.	tor.		
	ει /ε ⁰	2710	869	98.3	24.6	18.4	15.5	-	12.1	11.2	10.9			
	tan 6	6,62	2.95	3.90	1.66	0.41	0.18	1 1	0.081	0.004	0.018			
	د، /د		1	6940										
	tan 6d	!	!!!	2.03	;	268	21.4							
	μ' /μο	089	672	099	570	268	21.4							
	tan 6		1	1	90.0	0.42	3.9							-4-
	ει /ε°		!	1 1	1	11.9	!	11.2	11.0	11.0				•
	tan 6 _d	1	1	;	:	0.070	:	0.07	0.034	0.014				
	μ' /μ _ο		!	}	1 1	-	;	! ! !	3.53	0.57				
	tan 8		;		!!!!	-	!	1 1 1	2.50	6.75				
				/alues o	f tan 6 a	re multi	plied by	, 10 ⁴ ; f	requenc	Values of $\tan \delta$ are multiplied by 10^4 ; frequency given in c/s .	in c/s.			
	د، /د	;	1	1	1 1 1	-	!	!	!	1	6.34			
	tan 6		!	;	!	!	-	!	;	!	18			
	€1/€ 6.54	6.54	6.54	6.54	6.54	6.54	6.53	6.52	!	-	6.45			
	tan 6 11	7.2	6.0	5.3	3.9	2.7	5.0	7.2	1	1 1	24			
	ει /ε°	-	1	!	6.38	!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!	!	1	:	:	6.35	;	6.34	
	tan 6	1	! ! !	!	1.9	}	!	1		:	12.5		17.0	

a. Stupakoff. b. $83\%~{\rm Al}_2^{0}_3$, balance principally silica and calcium oxides. c. Western Gold and Platinum. d. $97\%~{\rm Al}_2^{0}_3$, remainder mostly MgO.

e. Gen. Ceramics. f. Ferroxcube. g. Amer. Lava. h. Ceramics School, Rugers University.

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$\frac{5\times10^{10}}{}$		-5-	
$\frac{2.4 \times 10^{10}}{7.45^{*}}$	6.20 195 6.24 246	5.59 165 5.69 173 5.65 160 5.73	5.43 103 5.44 129
1.4x10 ¹⁰ 7.51*	6.26 149 6.28	5.62 134 5.70 158 5.67 139 5.74	5.44 94 5.45 106 5.39 4.5 5.38 4.0 6.16
8.6x10 8.35 27	3.79 5.0 6.29 137 6.30	5.64 117 5.71 133 5.68 104 5.75	5.45
3x10 9			
1×10 ⁹			
3x10 ⁸ 8.5 6.6	3.80		
1x10 8.5 4.7	3.80		
1×10 8.5 3.0	3.80		
1x10 8.5 4.2	3.80		
1×10 8.5 11	3.80		
1x10 8.57 50	3.80		
1x10 8.66 170	3.80 4.1 6.82 186 7.07 257	5.95 58 6.01 73 6.03 6.05	5.62
$\frac{1 \times 10^2}{9.07}$	3.80		
ε'/ε _ο tan δ	e^{1}/ϵ_{0} $tan \delta$ e^{1}/ϵ_{0} $tan \delta$ e^{1}/ϵ_{0}	ϵ'/ϵ_o $\tan \delta$ ϵ'/ϵ_o $\tan \delta$ ϵ'/ϵ_o $\tan \delta$ $\tan \delta$	$ \frac{\epsilon'}{\epsilon_0} $ $ \tan \delta $
I A 2e. <u>Zircon</u> "AlSiMag" 475 ^{a,b} (density = 3.69 gm/cc)	I A 3. Glasses Corning 7910 Corning 8603: "Fotoform" B (843GU) "Fotoform" B (843GZ)	"Fotoform" C (843GZ) "Fotoform" E (843GZ) "Fotoform" E (843GZ)	"Fotoceram" (843GU) "Ceram" 61-1 ^c "Ceram" 61-2 ^c "Ceram" 61-2 ^c

a. Amer. Lava. b. Zircon porcelain. c. Corning. *Density = 3.43 gm./cc.

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$\frac{1.4 \times 10^{10}}{2.4 \times 10^{10}}$	6.14	2.0	5.85	2.5																		1.6	360	5.02	300
8.6×10	!	1	!!!	!	6.79	130	6.42	52	6.92	140	6.51	57	4.02	17	3.79	1.1	3.65	2.6		4.80	3.1	1.61	250	;	;
3×10^{9}		1	1 1 1		 	1 1	1		!	1 1		!	!	1	1 1	!		}		4.80	1.6	1.64	470	-	1
1x10 ⁹		1	1	•	1 1	1	-	i 1 3	!	1 1	1	1	1 1	1	;	1	1	1		4.80	0.57	1.74	460	;	
3x10 ⁸		1	1	!	6.84	55	6.44	28	6.98	64	6.53	28	4.05	11	!	-	!	!		}	i	1.60	250	:	1
1×10 ⁸	# ! !	:	1 1	i i i	6.88	47	6.46	25	7.00	51	6.55	23	4.06	9.3	-	1	;	1		4.15	;	1.62	170	;	1
1×10^{7}		;	1	1	6.94	40	6.49	19	7.06	45	95.9	18	4.06	6.8	;	;	:	}		4.15	!	1.64	140	}	!
1×10 ⁶		;	-	-	6.95	42	6.50	17	7.09	44	6.56	14	4.06	4.8	1	! !	;	† † †		4.15	1	1.67	170	!	!
1x10 ⁵	1	-	!	1	6.95	46	6.48	16	7.10	20	6.57	15	4.06	4.0	!	;	;	1 !		4.15	;	1.75	400		1
$\frac{1\times10^4}{1\times10^4}$	-	!	:	!	7.00	55	6.50	18	7.12	29	6.59	18	4.07	4.0	!	;	1	!		4.15	!	1.91	1180	1	† ! !
$\frac{1\times10^3}{}$;	!	1	7,05	20	6.50	19	7.16	78	6.60	21	4.07	5.8	1	;	!	; ; ;		4.15	;	2,45	4100	:	† † 1
$\frac{1\times10^2}{}$	1	1	1	;	7.14	95	6.52	21	7.26	115	6.64	30	4.07	7.4	;	-	!	1 1 1	•	4.15	;	4.81	6500	}	1 1
	e¹ /e	tan 6	e1/e	tan 6	ει /ε _.	tan 6	€1/€	tan 6	€¹ / €	tan 8	€1/€	tan 6	e¹ /e	tan 6	€¹ /€	tan 6	e1/e	tan 6		د، /د	tan 6	€1/€	tan 6	€1/€	tan 6
IA 3. Glasses (cont.)	"Ceram" 61-4 ^a		"Ceram" 61-5 ^a		Owens-Corning CR-262 ^b		Owens-Corning 57 M		Ownes-Corning EA63 ^b		Owens-Corning EA73		Owens-Corning X600 ^b		Fused Quartz, Clear		Fused Quartz, Translucent		TA 4 Miscellaneous Inorganics	Boron nitride (dried, field	d to direction of pressing)	"Fiberfrax" Board",		Silicon nitride (75%)	Boron nitride (25%) ^d

a. Corning b. Research samples (Owens-Corning Fiberglas). c. Syncor. d. Hot-pressed (Carborundum). e. Aluminum-silicate ceramic fibers. * Electric field \$\mathbb{L}\$ to direction of pressing.

Values of tan δ are multiplied by 10^4 ; frequency given in c/s.

8.93 6.86 5.07 4.8 2.0 1.0 1.0 1.0 4.0 1.0 1.0 1.0 3.46 3.41 3.48 3.48 3.6 3.6 3.6 3.6 5.07 1.0 1.0 1.0 5.07 1.0 1.0 1.0 3.6 3.6 3.6 3.6 3.71 3.6 3.6 3.6 3.71 3.6 3.6 3.6 3.71 3.6 3.6 3.6 3.71 3.6 3.6 3.6 3.71 3.6 3.6 3.6 3.71 3.6 3.6 3.6 3.71 3.6 3.6 3.6 3.71 3.6 3.6 3.6 3.71 3.6 3.6 3.6 3.6 3.6 3.6 3.6 3.71 3.6 3.6 3.6 3.6 3.6 3.6 </th <th>I A 4. Miscellaneous Inorganics (cont.)</th> <th>cont.)</th> <th>1×10^2</th> <th>1×10^3</th> <th>$\frac{1\times10^4}{1\times10}$</th> <th>$\frac{1 \times 10^{5}}{1}$</th> <th>1x10⁶</th> <th>1x107</th> <th>1×10⁸</th> <th>3x10⁸</th> <th>1x10⁹</th> <th>$\frac{3\times10^9}{}$</th> <th>8.6×10^{9}</th> <th>1.4x10¹⁰</th> <th>2.4x10¹⁰</th> <th>$\overline{5\times10^{10}}$</th> <th></th>	I A 4. Miscellaneous Inorganics (cont.)	cont.)	1×10^2	1×10^3	$\frac{1\times10^4}{1\times10}$	$\frac{1 \times 10^{5}}{1}$	1x10 ⁶	1x107	1×10 ⁸	3x10 ⁸	1x10 ⁹	$\frac{3\times10^9}{}$	8.6×10^{9}	1.4x10 ¹⁰	2.4x10 ¹⁰	$\overline{5\times10^{10}}$	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	oam" HiK (1000 ⁰ F)-2.5 ^a			2.62				!				:	2.49				
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$ \begin{array}{cccccccccccccccccccccccccccccccccccc$		η/ 1μ	1	1	1	:	!	! ! !		!	}	!	0.992				
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$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	foam" HiK (10000F)-3 ^a	د / د	;	3.02	! ! !	 	!!!	 	-	1	!	!	3.08				
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$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	ofoam" HiK (10000F)-5a	e'/e,		5.48	;		 		!	!	!	f f f	5.35				
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$		tan 6 _d	1	143	!	;	-	† † †	1	-	1 1 1	!	75				
$\begin{array}{cccccccccccccccccccccccccccccccccccc$		μ' /μ	1		:	-	1	1	 	1	 	! ! !	0.961				
tan 6 8400 2000 725 160 tan 6 8400 2000 725 160 tan 6 46 3.2 28 tan 6 6.76 5.10 5.07 tan 6 6.76 6.10 5.07 tan 7 6.76 6.10 5.07 tan 8 6.70 1.00 6.20 tan 8 6.70 1.00 6.20 tan 8 6.70 1.00 6.20 tan 8 6.70 1.00 6.20 tan 8 6.70 1.00 1.00 8.2 6.0 5.6 tan 8 6.70 1.00 1.00 8.2 6.0 5.6 tan 8 6.70 1.00 1.00 8.2 6.0 5.0 tan 8 6.70 1.00 1.00 8.2 6.0 5.0 tan 9 6.70 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.		tan 6		1 1		; ! !	:) !	! ! !	-	† †	!	101			-	
tan δ 8400 2000 725 160 ϵ''/ϵ_0 5.15 5.10 5.07 ϵ''/ϵ_0 1.25 5.10 5.07 tan δ 46 32 28 ϵ''/ϵ_0 1.25 1.0 1.05 6.8 5.5 4.8 tan δ 8550 3860 1930 7800 2900 1100 620 ϵ''/ϵ_0 4.55 3.80 3.55 3.49 3.46 3.44 3.43 1.7 22 ϵ''/ϵ_0 3.70 3.68 3.67 3.67 3.67 3.67 3.67 3.67 3.67 1.5 15 15 15 15 15 15 15 15 15 15 15 15 15	tone (50% R.H.)	e' /e,		13.9	8.93	98.9										-7-	7
then e^{i}/ϵ_{o} 5.15 5.10 5.07 tan δ 46 32 28 $\epsilon^{i}/\epsilon_{o}$ 1.2 tan δ 4.5 tan δ 4.5 δ		tan 6		2000	725	160											
hated) b,c $\tan \delta$ 46 32 28 28 $$	tone (baked, then	€¹ /€		5.10	5.07												
1/cc) tan δ	affin impregnated) ^{b,c}	tan 6		32	28												
t No. 1	amica" 500 ^d	€1/€		1	1		1	1 1	-	!	;	!	6.94				
$\begin{array}{llllllllllllllllllllllllllllllllllll$	nsity $3.04~\mathrm{gm/cc}$)	tan 8	-	!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!	!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!	.	! ! !	!	1	!		† † ;	24				
tan δ 86500 38600 19300 7800 2900 1100 620 $\epsilon^{1}/\epsilon_{0}$ 4.55 3.80 3.55 3.49 3.46 3.44 3.43 3.43 3. tan δ 3900 1300 400 190 82 60 56 54 tan δ 1240 590 210 78 23 17 22 $\epsilon^{1}/\epsilon_{0}$ 3.70 3.68 3.67 3.67 3.67 3.67 3.67	eisen Cement No. 1	€1/€		0.2	21	10.5	6.8	5.5	4.8								
$\epsilon'/\epsilon_{\rm o}$ 4.55 3.80 3.55 3.49 3.46 3.44 3.43 3.43 3.4 tan 5 3900 1300 400 190 82 60 56 54 tan 5 1240 590 210 78 23 17 22	ter wet grinding)	tan 6	86500	38600	19300	7800	2900	1100	620								
$\epsilon^{1}/\epsilon_{0}$ tan δ 3900 1300 400 190 82 60 56 54 $\epsilon^{1}/\epsilon_{0}$ 4.55 3.97 3.76 3.71 3.69 3.69 3.68 $\epsilon^{1}/\epsilon_{0}$ 3.70 3.68 3.67 3.67 3.67 3.67 3.67 3.67 3.67	eisen Cement No. 1	e' /e		3.80	3.55	3.49	3.46	3.44	3.43	!	3.43	3.43					
$\begin{cases} \epsilon^{1}/\epsilon_{0} & 4.55 & 3.97 & 3.76 & 3.71 & 3.69 & 3.69 \\ \tan \delta & 1240 & 590 & 210 & 78 & 23 & 17 \\ \epsilon^{1}/\epsilon_{0} & 3.70 & 3.68 & 3.67 & 3.67 & 3.67 \\ \end{bmatrix}$	er drying at 200 ^o C)	tan 6		1300	400	190	82	09	26	!	54	54					
$(1)^{6}$ tan δ 1240 590 210 78 23 17 $\epsilon^{1/\epsilon_{0}}$ 3.70 .3.68 3.67 3.67 3.67 3.67 3.79 $(2)^{6}$ tan δ 69 46 33 23 17 15	ı-ramic"	€1/€0		3.97	3.76	3.71	3.69	3.69	3.68							÷	
$\epsilon^{1}/\epsilon_{0}$ 3.70 .3.68 3.67 3.67 3.67 3.7 3 $\epsilon^{2}/\epsilon_{0}$ tan δ 69 46 33 23 17 15	received) ^e	tan 6		290	210	78	23	17	22								
tan 6 69 46 33 23 17 15	a-ramic"	€¹ /€		.3.68	3.67	3.67	3.67	3.67	3.67								
	er drying) ^e	tan 6		46	33	23	17	15	15								

a. Emerson and Cuming. b. Hunson. c. Paraffin treated (Lab. Ins. Res.). d. Mycalex. e. Spruce Pine Mica.

organic
Solids,
Ë.

<u>Plastics</u> (including plastics with fillers, laminates).	c	c	Va	lues of	tan 6 ar	e multi	plied by	10 ⁴ ; fr	couenca	Values of tan δ are multiplied by 10; frequency given in c/s.	ı c/s.			
$\frac{1 \times 10^2}{1 \times 10^3}$		1×10 ³	$\frac{1 \times 10^4}{1 \times 10^4}$	1×10^{5}	$\frac{1\times10^6}{1}$	$\frac{1\times10^7}{1}$	$\frac{1\times10^8}{}$	$\frac{3\times10^8}{}$	1×10	$\frac{3\times10^9}{}$	8.6×10^{9}	$\frac{1.4 \times 10^{10}}{}$	$\frac{2.4 \times 10^{10}}{}$	5×10^{10}
ει/ε _{ο 4.17 4}	4	4.12	4.06	3.95	3.80	3.66	3.52	!	3.50	;	3.43			
103	-	100	157	231	270	271	-275		312	!	360			
e'/e ₀ 3.75 3.	က်	3.72	3.69	3.61	3.51	3.40	3.32	;	3.29	3.28	33.27			
59		99	114	167	190	202	240	1	280	280	230			
$\epsilon^{1}/\epsilon_{0}$ 7.42 6.	9	6.03	5.25	4.73	4.21	3.85	3.61	-	3.50	!	3.32			
tan 6 1760 1	$\vec{\vdash}$	1060	922	900	208	517	440	:	364	!	377			
€' / € ₀ 3.99 3.	က်	3.88	3.78	3,68	3.56	3.45	3.35	3.30	3.24	3.20	3.13			
192	-	161	200	235	208	186	199	206	215	223	234			
ε' /ε ₀ 4.75 4.	4	4.54	4.35	4.18	4.05	3.90	3.74	!	3.62	ł 1	3.47			
346	23	295	270	261	245	248	310	1 - -	341	!	384			
ε' /ε ₀ 4.74 4.49	4.4	o.	4.30	4.15	4.00	3,85	3.70	3.63	3.54	3.49	3.44			
440 325	328		264	243	218	212	244	245	257	268	327			-
ε' / ε ₀	-	,	!!!	1	1 ! !	!	:	!	;	!	1.41			8-
	•		!	1 1 1	1	!	1 1 1	!	1 1	-	115			
ε' /ε ₀ 25.3 17.1	17.	_	10.5	6.64	5.11	4.72	4.60	4.5	4.74) (1	4.57	4.51	4.47	
2350 2880	288	0	3340	2610	1070	390	175	194	410	}	390	403 *	435	
Phenolic-"fiberglas" laminate e'/e 4.66 4.64	4.6	4	4.60	4.56	4.51	4.44	4.34	4.3	4.78	4.76	4.75	4.74	4.73	
35	.,,	39	99	69	72	98	111	151	160^*	190	\$ 250	* 280	330	
ε' /ε ₀ 4.01 3.98	3.0	98	3.95	3.91	3.87	3.84	3.78	3.7	;	}	4.23	4.23	4.22	
37 4	4	43	47	42	47	72	66	164	1 1 1	;	230	215^*	230	

IB1b. Melamine-formaldehyde

n Empereon and Cuming of "Departers 0598D9 8 or mot (Boutsocton Manhotton) mit 94% Constant to	070 41:00	Monhatta	00+0041	mot (Bo	o c	9596719	Dynatos	-	Cuming	bue no	F.mere	a. du Pont Textile Fibers Dent.
140		98 130 139 143	130	86	99	49	49	44	tan 5 46 46	46	tan 6	laminate) GM-1, (dried) ¹
3.91		3.98 3.95	1	4.52	4.57	4.59	4.59	4.60	4.62	4.69	$\epsilon^{1}/\epsilon_{0}$ 4.69 4.62 4.60 4.59 4.59 4.57 4.52	"Dilecto" (Melamine glass

a. du Pont Textile Fibers Dept. b. Emerson and Cuming. c. "Pyrotex 9526D2, 8 oz. mat (Raybestos Manhatten) with 34% Conolon 506 resin (Narmco) molded at 290°F, 200 psi and cured at temperatures to 400°F (Goodyear). d. 181-14 "Fiberglas" cloth with 31% resin as in (c), molded at 310°F, cured at 350°F (Goodyear). e. Composition same as (d) but with 3-ply bleeder. f. 50% Amer. Cyanamid 405 resin, 50% Owens-Corning T-36 glass mat (Continental Diamond).

*Sample not dried.

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IB1 c. Cellulose derivatives		1×10^2	$\frac{1\times10^2}{1\times10^3}$	$\frac{4}{1\times10^4}$	$\frac{1 \times 10^{5}}{1 \times 10^{2}}$	1×10^6	1×10^7	1×10^{8}	$\frac{3\times10^8}{}$	$\frac{1\times10^9}{}$	3×10^9	8.6×10	$\frac{1.4 \times 10^{10}}{}$	2.4x1010	5×10^{10}
"Forticel" JLB-(H) ^a	€1/€	3,59	3.57	3.51	3.41		3.18	3.08				2.89			
	tan 6	61	66	159	196	194	180	205	-	264	294	334			
"Forticel" JMB-(M) ^a	e' / e	3.94	3.89	3.82	3.70	3.55	3,41	3.25	:	3.06	2.97	2.88			
	tan 6	89	109	182	240	251	260	319	!	392	434	389		•	
"CTA" ^b	ε' / ε΄	4.11	3.99	3.86	3.67	3.51	3,38	3.23	; ; !	3.07	3.01	2.92			
	tan 6	140	206	277	306	306	281	218	!	191	206	226			
IB1d. Silicon resins															
Silicone Alloy C-1147 ^c	_{وا} / د	1	1 1 1	1	† - -	2.52	2.52	2.52	2.52	2.51	2.50	2.49	2.48	2.48	2.48
	tan ô	:	1	!	1	9.0	2.5	3,3	4.0	5.0	0.0	7.1	8.1	0.6	14.2
Silicone Alloy C-1328 ^c	e¹/e	}	1	1	1	2.50	2.50	2.50	2.49	2.49	2.48	2.48	2.48	2.48	2.48
	tan 6	;	:	1 1 1	:	1.2	3.4	2.2	1.9	2.8	3.2	4.0	4.4	4.8	5.9
DC 301 molding compound	€1/€	4.16	4.12	4.10	4.08	4.07	4.06	4.04							-:
	tan 6	63	63	53	49	20	51	29) -
DC 2105 laminate	€¹ / €°	3,98	3.98	3.97	3.96	3.96	3.96	3.96		4.18	4.17	4.16			
	tan 6	19.3	18.6	15.9	15	14.4	16.6	25	† † 1	28	61	69			
$^{ m f}$ DC 2106 laminate	€' / € 4.24	4.24	4.24	4.22	4.22	4.21	4.21	4.21	!	4.32	4.31	4.30			
	tan ô	23	18.2	15.2	12	14	17	23	:	45	52	99		•	
Silicone - asbestos	€1/€ 12.80	12.80	9.90	6.65	4.59	3.68	3,45	3.39	3,3	3.68	3.58	3.52	3.49	3.49	
laminate ^g	tan 6 1870	1870	2400	2650	2090	1020	460	20	45	200	340*	210^*	190	130	
Silicone - "fiberglas" laminate, ϵ'/ϵ_0 3.66	e1/e	3.66	3.63	3.61	3.60	3.59	3.58	3.56	3.5	3.91	3.88	3.85	3.83	3.81	
$_{ m pressed}$ (dried) $^{ m h}$	tan § 10.7	10.7	9.8	8.7	9.4	10.0	12.2	19	26	33*	*8 *	65 *	75*	113	
Silicone - "fiberglas" laminate, ϵ'/ϵ	. وا/د	3.13	3.13	3.13	3.13	3,13	3,13	3.13	3.1	;	3.84	3.80	3.78	3.75	
i bagged (dried)	tan 6	21.3	16.7	15.4	14	13.2	13.1	19.3	24	; ; !	56	* 0 <i>L</i>	* 88	110	

a. Cellulose propionate (Celanese). b. Cellulose tri-acetate (du Pont Film Dept.). c. Delaware Res. Dev. d. 45% chopped glass fibers, 20% silica, 35% polysiloxane resin (Dow-Corning). e. 50% EC-116 glass fabric, 50% polysiloxane resin (Dow-Corning). g. 50% "Pyrotex" felt 9526DB-5, impregnated with 50% DC-2106 resin (U.S. Polymeric), molded at 350°F, 300 psi, and cured at temperatures to 470°F (Goodyear). h. 65% 181-112 cloth, 35% DC-2106 resin molded at 315°F, cured at temperatures to 480°F (Goodyear). i. Composition same as (a), but with 3-ply bleeder, 33% resin.

* Not dried.

Values of tan δ are multiplied by 10; frequency given in c/s.

IB 1 e. Polyvinyl resins (1). Polyethylenes		1×10^2	1×10 ³	1×104	1×10 ⁵	1×10 ⁶	1×10^7	1×10 ⁸	3x10 ⁸	$\frac{1\times10^9}{}$	$\frac{9}{3\times10^9}$	8.6×10	1.4x10 ¹⁰	2.4×10 ¹⁰	5x10
"Fortiflex" A ^a	e'/e,		2.38	2.38	2.38	2.38	2.38	2.38			2.38	2.37			
	tan 6	1.1	0.37	0.25	<0.5	<0.3	<0.3	0.3	-	3.1	2.6	1.9			
"Marlex" 50 ^b	€1/€0	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2,39	2.39	2.38	2.38	2.38	
•	tan 6	1.6	0.33	0.28	<0.5	0.28	<0.3	0.32	0.9	2.4	2.15	1.6	1.9	2.1	
(2). Polyvinyl chloride-acetate															
"Boltaron" 6200-10 ^c	€'/€	!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!	}	1		1 1		\$! !	1 1	2.81					
	tan 6	1	1	1	! ! !	1 1	:	:	!!!	82					
(3). Polychlorotrifluoroethylene	91														
$" ext{KEL-F"} ext{X200}^{ ext{d}}$	€، /و°	3.13	3.00	2.84	2.70	2.56	2,45	2.36	:	2.30	2.28	2.27			
	tan 6	198	292	398	420	320	220	180	!	96	73	26			
(4). Polytetrafluoroethylene															
"Teflon" (77%) plus	£1/6	! ! !	!	!	!	; ; !	1	† ! !	*	2.38					-
calcium fluoride (23%)	tan 6	! ! !	!	;	!	!	!	1	1 6 1	22					10-
(5). Polyacrylates															
"Lucite" Type HC-202 ^f	د، /د	3.27	3.01	2.87	2.76	2.71	2.66	2.63	1	2.58	2.56	2.55			
	tan 6	290	446	300	202	142	90	63	-	43	37	33			
Acrylic impregnated	e, /e	3.76	3.47	3.25	3.10	2.98	2.91	2.84	;	2.77	2.74	2.72			
Orlon batt ^g	tan 6	664	503	362	277	213	168	118	!	98	72	59			
(6). Polystyrene															
Polystyrene impregnated	ε, /ε _ο	3.11	3.10	3.10	3.10	3,10	3.10	3.10	;	3.16	3.16	3.16			
"Fiberglas" g	tan 6	22	24.6	18.2	15.6	4.6	6.1	11.3	;	28	39	36			
Polystyrene impregnated	e' /e	3.02	3.01	3.00	3.00	3.00	2.97	2.91	;	2:87	2.84	2.82			
"Dacron" batt	tan 6	43	30	32.6	46	09	43	78	!	113	130	157			
Polystyrene impregnated	e, /e	3.09	2.98	2.92	2.89	2.87	2.86	2.85	-	2.89	2.88	2.87			
"Orlon" batt	tan 6	211	159	113	78	45	33	36	• • • • • • • • • • • • • • • • • • • •	56	28	36			
"Eccofoam" PS (K=1,2) ^h	ε' /ε ₀	!	!	1 1 1	-	; ; ;	:	-	!	-		1.182			
	tan 6	!	;	;	;	;		!		!		1.2			

a. Linear polyethylene (Celanese). b. Low pressure, hi-density polyethylene (Phillips). c. 100% unplasticized polyvinyl chloride (Hartwell). d. Kellogg. e. Ethylene Chem. f. Methyl methacrylate (du Pont Polychemicals). g. du Pont Textile Fibers Dept. h. Samples also measured having $\epsilon^{1}/\epsilon_{0} = 1.362$, tan $\delta = 0.00165$ (Emerson & Cuming).

Values of tan δ are multiplied by 10; frequency given in c/s.

IB 1 e. Polystyrene (cont.)			(ı			ć	c	c	*	-	
(7). Miscellaneous polystyrenes	Ωį	$\frac{1\times10^2}{1}$	$\frac{1\times10^3}{1}$	1×10^4	1×10^{5}	1x10 ⁶	1x10,	1x108	3x108	1×10^9	3x10 ⁹	8.6x10	1.4x1010	$\frac{2.4 \times 10^{10}}{}$	$\frac{5 \times 10^{10}}{}$
Polytrifluorostyrene (film) ^a	e1/e	2.56	2.56		2.56		2.56	2.56	-	!	!	2.54			
	tan 6	34	27	16.5	14	6.2	6.3	6.9	:	!	;	19			
b Polycyclostyrene	€¹ /€	1	1	!	:	;	1	-	<u> </u>	1	2.51	2.49			
	tan 6	!	1 1) 	!!!!	1 - - -	! ! !	1	!	1 1	31	56			
(8). Styrene copolymers, cross linked	s linked											٠			
"Pelron" 9420 ^c	€¹ /€	;	!!!	-	-	 	-	[; ;	}	2,59	2.54				
	tan 6	t 1 1	:	; ; !	!	-	i ! !	-	1	22	29				
"Pelron" 9422 ^c	€¹ /€	; ; !	1	-	-	!	-	1	!	2.61	2.61				
	tan 6	!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!	!	1 1	;	1	!!!	!	1	44	51				
"Pelron" 9423°	€1/€0	}			!	1	1	!		2.62	2.61				
	tan 6	 	1 1	 	1	!	; ; ;	!	!!!	20	59				
"Pelron" 9424 ^c	€1/€	1 1 1	. !	1 1	1 1	1	!!!		!	2.60	2.60				
	tan 6	1 1 5	! !	-	-	;	! ! !	 	 	30	39				-1
"Ecco" L65 ^d	e, /e,	!		-	1 1 1	!	1 1 1	; ; !	!!!!	2.58	2.58				1-
	tan 6	-	1		1	: :	!	!	! ; !	30	34				
"Stycast" LoK ^d	€¹ /€ ₀	1			!!!	1 1	!	!!!				1.68			
	tan 6	1	1	[] [!	1 1 1	!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!	!!!!	:	:	-	26			
"Stycast" HiK (K=7) ^{d,e}	e' /e	7.25	7.15	7.08	7.06	1	7.03	1 1 2	!	!	!	6.85			
	tan 6	66	61	36	23	!	9.5	!!!	!	!		11			
"Stycast" TPM-3 ^d	€1/€0	2.40	2.40	2.40	2.40	2.39	2.37	2,36	1	:	!	2.35			
	tan 6	2.9	1.7	1.9	2.8	7.3	7.2	5.8	!	!	!	4.6			
"Rexolite" 2101 ^h	€1/€0	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.72	!	1	2.75			
	tan 6	13.5	9.6	7.5	2	4	6.5	10	12	† 1 †	!	19			
IB1f. Polyesters "Atlac" 382 (70%)-styrene	د،/د	3.08	3.05	3.02	3.00	2.96	2.92	2.87		2.82	2.78	2.72			
(30%) ⁱ	tan 6	82	75	70	80	110	132	142	!	135	120	105			

a. Polaroid. b. Monsanto, Ohio. c. East Coast Aeronautics. d. Emerson and Cuming. e. Manufactured with K=3 to 15. h. "Fiberglas" laminate (Rex). i. Atlas Powder.

Values of tan δ are multiplied by 10^4 ; frequency given in c/s.

10 5×10 10													-:	12-														
2.4×10^{10}													2.94	288														
1.4×10^{10}													2.96	410														
8.6×10^9	2.65	75	1.65	200	4.30	106	2.86	114	2.82	129	3.28	380	;	;	2.98	89	3.01	113	2.65	93	2.91	26	2.89	92	3.08	89		
3×10^{9}		95	1.67	200	4.35	102	2.93	124	2.89	130	3.42	470	!	1	2.99	81	3.02	105	;		2.96	105	:	!	3.11	92		
1×10		108	1.69	235	4.40	95	2.97	147	2.91	145	3,55	570	!	!	3.00	98	3.03	144	2.74	92	3.00	113	2.92	84	3.13	100		
3x10 ⁸		1	! ! !		:	:	!	-	!	!	:	!!!	-	!	3.03	123	;) 	1	1	3.05	126	1	!	3.15	120		
1×10 ⁸		115	1.73	240	4.40	120	3.11	160	2.94	128	3.86	009	3,33	320	3.05	143	3.07	202	2.71	137	3.09	137	2.54	167	3.18	139	3.39	125
1×10^7		06	1.78	210	4.43	96	3.17	143	2.97	87	4.15	200	3.47	195	3.13	179	3.15	223	2.77	152	3.22	185	2.77	197	3.24	170	3.51	141
1x10 ⁶		73	1.84	200	4.45	77	3.26	148	2.98	82	4.42	370	3.56	161	3.20	182	3.26	226	2.83	152	3.32	261	2.86	228	3.31	186	3.60	160
1×10 ⁵		54	1.90	218	4.50	63	3.32	125	3.02	79	4.70	370	3.63	162	3.28	152	3.37	185	2.86	127	3,45	283	2.93	233	3.40	187	3.68	179
$1x10^{4}$		44	1.97	255	4.53	41	3.36	78	3.06	46	4.98	370	3.71	162	3.32	98	3.47	135	2.89	80	3.59	255	3.04	196	3.50	184	3.78	201
$1x10^3$		44	2.05	396	4.57	45	3.40	61	3.06	27	5.26	360	3.81	172	3.35	51	3.53	111	2.96	47	3.72	239	3.12	146	3.61	200	3.90	258
$1x10^2$		42	2.22	1006	4.65	48	3.43	65	3.11	22	5.55	360	3.91	202	3.37	48	3.61	119	2.99	39	3.84	309	3.16	133	3.72	277	4.08	337
	e' /e	tan 6	د، /د	tan 6	E1/E	tan 6	ε¹ /ε _ο	tan 6	د، /د	tan 6	ε ^ι /ε ₀	tan 6	€' /€	tan 6	ε¹ /ε ₀	tan 6	e' /e	tan 6	ε, /ε ⁰	tan 6	ε' /ε ₀	tan 6	ε' /ε ₀	tan 6	e' /e	tan 6	e' /e	tan 6
IB1f. Polyesters (cont.)	"Atlac" 382 (50%) - styrene	(50%) ^a	"Bakelite" PLLA-5005 ^b		"Dilecto" (glass mat polyester)	GM-PE (dried) ^C	Celanese MR-31C		Celanese MR-33C		Celanese MX-186		Celanese MX-218		Polyester impregnated	"Dacron" batt ^d	Polyester impregnated	"Dacron" batt	Polyester impregnated	woven "Dacron" fabric	Polyester impregnated	"Nylon" batt	Polyester impregnated	woven "Nylon" fabric	Polyester impregnated	"Orlon" batt	Polyester impregnated	woven "Orlon" fabric

a. Atlas Powder. b. Phenolic spheres in polyester resin (Bakelite). c. Continental Diamond. d. Rohm and Haas', "Paraplex" P-43 resin (du Pont Textile Fibers Dept.).

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1.4x10 ¹⁰																										
8.6×10^9	3.19	44 *	2.90	82	17.8	3700	23.2	2700	19.5	2700	12.8	1600	9.1	1500	42	5300	22	8900	3.67	128	3.62	168	3,73	143	2.89	155
$\frac{3\times10^9}{}$		61	2.96	105	}	-	1 1 1	1 1	; 1 1	-	!		1	-	! ! !	1	1 1	1	3.68	141	3.63	148	3,75	143	1	! ! !
1x10		92	3.01	120	!	:	!	!	! ! !	!		1 1	!	;	!	!	:) 	3.70	135	3.68	141	3.78	118	;	!
3×10^{8}	1	;	;	;	!	!	!	-	1	!	-	1	;	;	;	:		;	 	!	 	;	;	-	1	
1×108		130	3.10	150	;	;	 	!	1	 	1	!	!	!	1 1 1	;	!	1		1 - 	}	1 1 1	!	!		‡ †
1×10^7	2.92	160	3.17	170	; ;	† † !	1	1	!	1	! ! !	! ! !	1	-	1070	*_	1070	2.8	!	{	!	!	1	;	1 1	!
1×10		166	3,23	175	1	! ! !	 - -	:	 - -	1	-	1	1	:	6200	12*	2400	* 45	1	-	! ! !	1 1	1 1 1	! ! !	1	1 1
1×10^{5}	3.07	145	3.29	140	! ! !	! ! !	1	1 1	1 1	!	1 1	!!!	; ; ;	}	3,000	*88	000,9	*88	!	1 1	:	!	!	1	. 1 . 1 . 1	1
1x104		89.9	3,33	84	1	1		1	! ! !	1	-	!!!!	 	1	3,000 23,000	330	0,400 16,000	304	! ! !	 	1	;	 	-	!	1 1
$\frac{1\times10^3}{1}$	3.15	41.0	3,36	36	1	!	!!!	1 1	1	1 .	1	1		:	2	!	2	!		!	1	!	1	!	!	1
1×10^2	3.17	19.1	3.37	15) ! !	! ! !	1	-	!	;	!		- I - I - I	!	1	1	-		1	1	# # 1		!	1	!	1
	ε' / ε _ο	tan 6	è¹ / €	tan 6	ε ^ι / ε _ο	tan 6	e' / e	tan 6	e¹/e0	tan 6	€¹ / €	tan 6	e' / e	tan 6	€¹ / €	tan 6	€¹ / €	tan 6	€1/€	tan 8	€1/€	tan 6	e' / e	tan 6	ε' /ε ₀	tan 6
IB1f. Polyesters (cont.)	"Mylar" A ^a electric field	to film	"Cronar"b		"Eccosorb" HF155		"Eccosorb" HF680 ^C		"Eccosorb" HF853 ^c		"Eccosorb" HF1000		"Eccosorb" HF2050		"Eccosorb" HFX122		"Eccosorb" HFX123 ^{C,e}		Hooker 32A, "Fiberglas"	cloth laminate $^{ m f}$	Hooker 32A, "Fiberglas"	mat	Hooker 32A, "Fiberglas"	mat with fire retardent	"Selectron" 5084	

Values of tan δ are multiplied by 10^4 ; frequency given in c/s.

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 5×10^{10}

IR1 g. Enoxy resins	*	1×10^{2}	1×10^{3}	1×10^{4}	1×10^{5}	1x10 ⁶	1×107	1×10 ⁸	3×10^8	1×10^9	$3x10^9$	8.6×10	1.4×10 ¹⁰	2.4×10 ¹⁰	rC
"Dilecto" (Epoxy-glass laminate) ϵ'/ϵ			5.16	5.10	4.99	4.90	4.76	4.66	4.82		4.67	4.64			
GB-116E ^a t		46	72	118	176	185	205	233	162	170	176	213			
"Dilecto" (Epoxy-glass laminate) $\epsilon'/\epsilon_{\rm s}$ 5.25	:1/€ 5.5		5.21	5.12	5.00	4.91	4.75	4.63	4.65	4.54	4.48	4.42			
GB-126E ^a t	tan 6	09	74	136	190	192	202	223	175	186	182	210			
"Dilecto" (Epoxy-glass laminate) ϵ '/ ϵ	ει / ε 5.25		5.21	5.14	5.03	4.90	4.77	4.65	4.85	4.80	4.73	4.64			
GB-181E ^a t		42	29	131	178	204	226	268	165	179	202	218			
gnated	€¹/€ 4.12		4.08	4.00	4.84	3,66	3.49	3.37	1	3.25	3.21	3.16			
	tan 6	49	107	208	277	290	300	300	1	270	260	240			
,d	د'/د 3.71		3.69	3,66	3,59	3.49	3,39	3,30	1 1	3.18	3.15	3.12			
woven "Dacron" fabric t	tan 6	32	51	102	158	194	248	256	!	310	300	250			
	e'/e 4.62		4.48	4.28	4.03	3.78	3.64	3,45	1 1	3.24	1 1	3.06			
"Nylon" batt ^b	tan 6 189	89	253	369	407	336	323	330	1	320	!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!	280			
ted	€ 1/€ 4.34		4.26	4.11	3,91	3.72	3.61	3.53	!	3,33	3.25	3.12			
woven "Nylon" fabric ^b	tan 6 13	125	183	285	334	304	314	343	!	320	310	270			
	€1/€ 4.42		4.23	4.07	3.93	3.81	3.69	3.54	! ! !	3.32	!	3.15			
"Orlon" batt	tan 6 3	332	284	257	235	203	233	268	1	204	1 1	181			
	€¹ /€ 4.35		4.18	4.02	3.89	3.76	3.68	3.57	!	3,45	3.38	3.32			
woven "Orlon" fabric	tan 6 304	04	251	236	229	215	237	310	1 1	310	300	280			
	ει/ε, μι/μ	_	;	; ! !	:	;	}	! ! !	:	1 1 1	1 1	2.41			
$(K = 2.4)^{C} $ t	tan 6 _d + tan 6		; ; ;	1 1	!	1 1 1	-	! ! !	-	!		160			
"Eccofoam" HiK (500°F)	$\epsilon^{1/\epsilon}_{0} \cdot \mu^{1/\mu}_{0}$) 1 1	:	-	:	† 	1 1	1 1	!	:	4.53			
$(K = 4.5)^{C} $ t	tan 6 _d + tan 6		¦	1	1	1	1	 	1 1 1	}	!	270			
"Eccofoam" HiK (500 ^o F)	دا/د ۲۰۱۳ الم		:	!	1 1 1	;	;	!	1 1 1	;	-	5.85			
$(K = 5.9)^{c}$ t	tan 6 ₄ + tan 6	tan 6 m		!	1 1	!	;	 	1	1 1	1	460			
HiK (500 ⁰ F)	ε' /ε ₀ · μ' /μ _ο	` _	: !	!	-	-	-	1	1 1	1	1 1	7.54			
$(K = 7.5)^{C} $ t	tan 6 + tan 6	tan 6 n	m.	1	!	-	1	1	1	!	;	460			

a. Continental Diamond. b. du Pont Textile Fibers Dept. c. Emerson and Cuming.

Values of tan δ are multiplied by 10^4 ; frequency given in c/s.

 5×10^{10}

2.4×10 ¹⁰																		. •								
1.4x10 ¹⁰																										
8.6×10	3.95	326	1.115	880	5.00	334	1.40	1890	8.60	338	1.66	3900	13.6	220	1.12	0009	17.2	380	1.96	7300	2.81	116	!	!	3.10	370
3×10	!	1 1 1 1	1	1	1	1 1	! ! !	[!	!	1 !	1	;	}	2.34	4820	!	!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!	2.57	2600	2.82	.120	3.27	099	3.23	570
1×109	:	1 1		1	! !	-	-	;	!	!	!	1 1 1 1	1	ļ	3,75	2650	; ; ;	-	4.31	2950	2.84	132	3.30	635	3.40	670
3×10^{8}	 	! !	1	l	! ! !	1	! ! !	t 	!	!	1	! ! !	-	1 1 1	3.90	570	1	1	4,69	260	!	:	1	1	!	!
1×108	1	 	 	; ; . !) ! !	1	-	!	!	1 1 1	!	1 ! !	16.9	394	4.20	<200	19,6	420	4.80	<200	2.90	180	4.3	1100	3.70	1150
1×10^{7}		-	1 1 1	-	!!!	1		;	!	; ; ;		-	17.1	307	4.22	00 ₽	19.9	390	4.85	<20	3.01	146	5.8	2300	4.35	1140
$\frac{1}{1}$		-	1 1 1	; ; !	1	1 1		!	1	!		1 1 6 1	18.1	254	4.22	<100	21.4	360	4.85	<100	3.10	133	7.3	1000	4.90	096
1×10^{5}		234	1.33		6.55	247	1.67		10.8	255	2.64	!	18.5	228	4.22	1	; ; ;	:	4.85	1	3.15	108	8.1	540	5.60	840
1×10^4		161	1.33	-	6.72	162	1.67	1	11.2	181	2.64	-	19.2	177	4.22	; ; ;	23.2	250	4.85		3.19	74	8.9	670	6.45	1040
1×10^3		}	1	;	!	-	-	1	1	-	-	}	19,6	128	4.22	; ; ;	23.9	144	4.85	! ! !	3.21	44	9.4	1160	7.56	1450
1×10^2	1	{ ! !	! !	;	;	1	1	}	-	i	!	-	19.9	134	4.22	!	24.2	94	4.85	;	3.22	34	9.7	2600	8.80	2500
	€1/€	o tan کم	μ' 'μ	tan δ_{m} .	 €¹ /€	tan 6	μ' /μ	tan 6	ει /ε _ο	tan 6	μ, ιμ	tan 6	ε¹ /ε ₀ 19.9	$\tan \delta_{d}$	μ' /μ 4.2	tan 6	ε' /ε _ο 24.	tan 6 d	μ^{1}/μ_{0} 4.85	tan 6	€' /€ 3.2	tan 6	€1/€	tan 8 5600	€¹ / €	tan § 2500
																	*									
IB 1g. Epoxy resins (cont.)	"Eccosorb" MF110 ^a				"Eccosorb" MF112 ^a				"Eccosorb" MF114ª				"Eccosorb" MF116 ^{a,b}				"Eccosorb" MF117a,c				"Hysol" 6000 HD ^d		"Hysol" 6030-B ^d		"Hysol" XL-6060 ^d	

a. Emerson and Cuming. b. 81.2% Carbonyl iron, 18.8% resin. c. 85.8% Carbonyl iron, 14.2% resin. d. Houghton Labs.

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IR 1 a Frow resine (cont)		1~10	1 ~ 10 3	1×104	1~10	1 2 1 0 6	12107	1 4108	34108	1410	32109	9 6510	1 4.4010	9 41010	510
"Hvsol" XE-6080 ^a	e1 / E	3.70	3.55		3 34	3 28	3 20	3 06				2.81	O TVI	0141.7	0140
	,0 ,		0 9		1 96	7		070		, t	707	, t			
ī	raii o		80	00	170	134	700	0.7	! ! !	612	134	Lan			
"Scotchply" type 1001	€¹ / €	09.9	5.98	5,59	5.32	5.10	4.89	4.71	-	4.59	4.48	4.38			
(molded, uncured)	tan 6	571	458	342	207	219	288	384	:	450	470	460			
"Scotchply" type 1001 ^b	e! / e	5.18	5.12	5.02	4.92	4.82	4.68	4.57	!	4.56	4.56	4.56			
(cured)	tan 6	78	97	139	166	184	199	194	:	178	168	152			
"Epon" 828-curing agent CL	e¹ / e	4.56	4.48	4.34	4.12	3.91	3.72	3.55	-	3.29	3.23	3.23			
	tan 6	61	150	290	370	340	340	360	-	310	310	330			
"Epon" 828-curing agent D ^c	€1/€	3.58	3,55	3.52	3.47	3,36	3.27	3.18	1	3.03					
	tan δ	27	45	88	170	230	270	240	:	250					
"Epon" 828-curing agent	e¹ / e	3.61	3.61	3,59	3.56	3.47	3,38	3.27	!	2.94					
piperidine ^c	tan 6	18	23	26	130	180	220	260	8 8 1	270					
"Epon" 828-curing agent	e! / e	3.84	3.84	3.79	3.68	3.51	3.37	3.30	3.14	3.05	3.00	2.97	2.94	2.93	-1
BF_3 -400 $^\mathrm{c}$	tan ô	44	64	135	257	312	305	280	250	222	202	203	210	186	16-
"Epon" 828 "fiberglas" laminate, ϵ'/ϵ_0	ε, /ε	4.82	4.79	4.74	4.68	4.60	4.47	4.32	! ! !	4.34	4.28	4.25	4.22	4.21	
curing agent $\mathrm{BF_3} ext{-}400^\mathrm{c,d}$	tan 6	46	41	69	124	171	182	168	:	135	131	131	148	192	
"Epon" X131 "fiberglas"	€1/€	5.46	5.42	5,38	5.27	5.24	5,06	4.84	;						
laminate, No. 51 ^c	tan 6	39	40	62	124	184	246	304							
IBIh. Miscellaneous plastics															
"Penton" ^e	ει /ε _ο	3.03	2.99	2.95	2.92	2.88	2.85	2.81	}	2.73	2.70	2.63			
	tan 6	112	86	85	43	98	124	170	1 1 1	196	155	112			
"Policap" [†]	ει /ε	4.12	3.80	3.40	3.05	2.88	2.82	2.80		2.75	2.75	2.75			
	tan 6	444	999	748	513	233	107	71.5	1	62.0	09	52			
IB 2. Waxes															
Morse 200	ει /ε ⁰	2.34	2.34	2.34	2.34	2.34	2.3								
	tan 6	9.1	9.7	7.0	5.9	10	10								

a. Houghton Labs. b. "Fiberglas" laminate (Minn. Mining). c. Shell. d. 181-"Volan" A cloth pressed at 125°C, cured at 330°F, 200 psi, post-cured 4 hours at 200°C; resin content 23.8%. e. Chlorinated polyether (Hercules). f. Lovell.

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IB 2. Waxes (cont.)		$\frac{1\times10^2}{1}$	1×10^3	1×10^4	1×10^{5}	1×10^6	1×10^{7}	1×10^{8}	3×10^{8}	1×10	$3x10^9$	8.6×10^9	1.4x10 ¹⁰	2.4×10^{10}	12.7
Morse 280	e1/e	3.30	3.03												
	ťan ô	620	069	099	290	99	53								
Morse 300	e! /e	3.74	3.07	2.71	2.64	2.61	2.60								
	tan 6	1810	1030	490	189	83	46								
Morse 400	ε [‡] /ϵ	2.88	2.74	2.68	2.62	2.58	2.52								
	tan 6	474	267	136	103	152	87								
Morse 6060-C	e! /e	2.18	2.17	2.15	2.14	2.11	2.11								
	tan 6	52	26	41	20	2	က								
Morse 6062	e1/6	2.31	2.31	2.31	2.31	2.28	2.25								
	tan δ	13.5	10	11	10	11	6								
I B 3. Miscellaneous organics															
"Missileon" $^{\mathrm{a}}$	و، / و 9.00	00.9	5.14	4.69	4.43	4.25	4.08	3.98	1		1	3.88			
	tan 6	1410	870	200	330	280	260	260		}	!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!	260			
"Rocketon"	e1/e	7.66	5.88	5.03	4.58	4.29	4.11	3,99		1 1 1	; ; ;	3.95			
	tan 6	2280	1500	860	540	360	320	350	! ! !		!	440			
"Rocketon" (Modification 30)	e1/e	4.46	4.13	3.97	3.86	3.80	3.73	3.68	1	 	1	3.59			
	tan ô	774	430	223	163	125	124	142	1	!		220			
Irvington varnished linen tape	€¹ /€ 0	!	!	† † †	4.22	1 .	2.58								
	tan 6	† † †	1	!	513	1	260								
"Scotch" tape No. 39	ει /ε ₀		1 1 1	!	1	!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!	3.34 (a	3.34 (at 3x10 ⁷)	_						
	tan 6	!	!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!	1 1	!	1 1	390 (a	$390 \text{ (at } 3x10^7)$	_						
Sealing Compound EC-612	ε1/ε ₀		1	1 	1	1	1	1 1 1	1	\$ 1 1	17.4				
	tan 6	-	!	!	! ! !	1 1 1	!	1 .		1 1	1140				
"Ferrotron" 119 (core)	e1/e	31.8	29.1	27.9	27.2	26.8	26.3	25.2	!!!	24	24	24	20		
		1130	460	230	160	130	144	150	† 	<200	<200	<1500	<1000		
	η' 'μ	1 1	7.10	7.10	7.10	7.10	66.9	6.2	1 .	6.28	4.60	1.96	0.98		
	tan 6 m	1		1 1 1		10	20	65		3000	0019	14,500	20,600		
a. Haveg. b. Minnesota Mining.	c. Polymer	mer Co	Corp.		•										

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2.4×10^{10}		150	0.84	8400	11	140	0.44	24,000																			
1.4×10 ¹⁰		!	1		!	[]]		1 1																			
8.6×10	*0*8	130	1.19	* 0068	15	<1000	1.60	12,900															2.30	930	2.26	*068	
3×10^9		!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!	1 1 1	-	15	<500	3.56	5300															2.51	420	2.50	870	
1×10^9	1	† † †	3.4	2400	15	120	4.93	3000															2.54	150	2.63	470	
3x10 ⁸			;	;	-	1	1	}															2.54	44	2.65	190	
1x108	-	-	3.6	300	15	61	5.4	350															2.55	14	2.68	70	
$\frac{1\times10^{7}}{}$	14.8	80	4.7	80	15	59	5,65	<200															2.55	1.3	2.69	7	
1x10 ⁶	15.0	98	4.7	20	15.1	34	5.54	< 20	4.0	300	3.5	250	3.2	28	2.8	14							2,55	<0.3	2.69	0.7	
1×10 ⁵	15.2	90	4.7	-	15.1	28	!	1 1	:	!!!	1 1	1	-	}	!	!							2.55	<0.3	2.69	\ 1	
$\frac{1\times10^4}{}$	15,3	130	4.7	1	15.5	108	1	! !	!	[!	-	;	-	!	-							2.55	<0.3	2.69	<0.3	
$\frac{1\times10^{3}}{1}$	15.5	300	4.7	1	15.5	250	!	1 1	4.5	300	3.9	360	3.3	82	2.8	42			1.45	< 2			2.55	0.2	2.69	0.2	
$\frac{1 \times 10^2}{1}$	16.5	460	1		15.8	380	! !	; ! !	!	-	!	!	1 - -	;	-	!			:	!			2,55	1.4	2.69	2.2	
$\frac{1}{1}$ $\frac{1}{1}$ $\frac{1}{1}$	€' / €	$\tan \delta_{\mathbf{d}}$	η, /μ	tan 6 m	$\epsilon^{1}/\epsilon_{0}$ 15.8	tan 6	μ' /μ ο	tan 6 m	د ا /د	tan 6	د، /د	tan 6	ει /ε _ο	tan 6	e¹ /e	tan 6			e1/e,	tan 6			د، /د₀	tan 6	e! /e	tan 6	,
IB 3. Miscellaneous organics (cont.)	"Ferrotron" $308 \text{ (rod)}^{\mathrm{a}}$				"Ferrotron" 309 (tape) ^a				npregnated Kraft		Varnished glass cloth ^c		shed glass cloth,	flexible ^{c, d}	rnished glass cloth,	$_{ m stiff}^{ m c,d}$	I C. Liquids	1. Inorganic	Nitrogen -1950e		2. Organic	a. Aliphatic	"Kel-F" Alkane 464		"Kel-F" Alkane 695 ^g		

a. Polymer Corp.
 b. ASTM type A paper (D 1305), vacuum-impregnated with Sterling M50 (Sperry test sample).
 c. Sperry test sample.
 d. R-63 varnish (Union Carbide and Carbon).
 e. Cryogenic Eng. Lab, M.I.T. f. Chlorotrifluoroethylene dimer (Kellogg).
 g. Ibid., trimer.
 *Freq = 9.5 x 10⁹

Values of tan δ are multiplied by 10^4 ; frequency given in c/s.

I C. Liquids (cont.)					}				•		0				
2. <u>Organic</u> a. <u>Alip</u> hatic		$\frac{1\times10^2}{1}$	$\frac{1 \times 10^2}{1 \times 10^3}$	1×10^{4}	1×10^{5}	1x10 ⁶	$\frac{1\times10^{7}}{1}$	1×10 ⁸	3×10^{8}	$\frac{1}{1\times10}$	3×10^9	8.6×10^{9}	1.4x10 ¹⁰ 2.4x10 ¹⁰	10 5x10 ¹⁰	010
"KEL-F" Alkane 8126 ^a	€'/€ 2.88	2.88	2.88	2.88	2.88		2.88	2.87	2.80	2.61	2.37	2.16			
	tan 6	1.5	0.15	<0.1	<0.4	2.8	28	275	650	1080	066	684			
"KEL-F" Alkane 10157 ^b	e¹/e	2.88	2.88	2.88	2.88	2.88	2.88	2.70	1 1	2,39	2.28	2.23			
	tan 6	<0.2	<0.1	0.1	1.0	9.6	96	710	1 1	780	480	335			
"KEL-F" Alkane 12188 ^c	e, /e,	2,94	2.94	2.94	2.94	2.94	2,90	1 1	!	2,33	2.24	2.23			
	tan 6	<0.2	<0.1	9.0	5.7	55	550	1 1	!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!	485	330	218			
d Hexane	e'/e	1	1	1.84											
	tan 6	!	1 1	۸ 1											
b. Aromatic										-					
OS-45 ^e	ε' /ε _{0 2.65}	2.65	2.65	2,65	2.65	2.65	2.64	2.63	!	2.48					
	tan 6	3400	336	34	21	42	41	130	!	482					
OS-59, tetra alkyl silicate	€1/€ 2.46	2.46	2.46	2.46	2.46	2,46	2.46	2.46	!	2.41	2.33	2.24			
ester	tan 6	12.4	1.3	0.2	<0.3	<0.6	ıc	50.	1	324	410	380			-19
OS-82, monoisopropyl biphenyl	€'/€ 2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.60	2.57	2.52	2.51				-
		150	15	1.5	9.0>		12	115	220	183	100				
Diisopropyl biphenyl	e, /e	2.54	2.54	2.54	2.54	2.54	2.54	2.53	2.49	2.44	2.41				
	tan 6	9	9.0	0.2	<0.4	1.9	19	135	190	120	99				
"Selectron" $5084 \mathrm{monomer}$	e 1/e	:	1	; ; ;	1	!	;	1 1 1		1 1		3.01			
	tan 6	1	!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!		1		! ! !	!!!		1 1	!!!	410			
"Stypol" 16B monomer ^g	e'/e	! ! !	!	7.16			1 1			!	:	3.02			
:	tan 6	 	 	79	1 1		1 1 1	1 1 1	! ! !	t ! !	i i i	420			
c. Petroleum oil												*			
Jet fuel JP-4	ε1/ε ₀	:	1 1	!	!	!!!	! .	1	!!!	! ! !] - - -	2.04			
	tan 6	-	!	† † !	1	1 1	1	1	1 1	1	!	30			

a. Chlorotrifluoroethylene tetrameter.
b. Ibid., pentamer.
c. Ibid., hexamer.
d. Phillips.
e. Monsanto (St. Louis).
f. Pittsburg-Corning.
g. Robertson.
*
Freq = 9.5 x 10.

Values of tan δ are multiplied by 10 4 ; frequency given in c/s.

2.81 2.74 2.81 2.	I C 2 d. Silicones		$\frac{1\times10^2}{1}$	$\frac{1\times10^2}{1\times10^3}$	1×104	1×10^{5}	$\frac{1\times10^{6}}{}$	$\frac{1\times10^{7}}{1}$	$\frac{1\times10^{8}}{}$	$\frac{3\times10^8}{}$	$\frac{9}{1\times10}$	3×10^9	8.6x10 ⁹ 1.4x10 ¹⁰	$\frac{10}{2.4 \times 10^{10}}$	5×1010
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Grease a	€، /و		1	!	1		!			!	2.80	2.74		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$!	!	:	-	-	-	1	;	1 1	80	200		
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$		€¹ /€ 0	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.80	2.79	2.67	2.41		
$e^{i}/\epsilon_{o} =1.00058 = =1.00058 = 1.0$ $e^{i}/\epsilon_{o} = = -1.0403 = -$		tan 6	က	0.3	<0.1	<0.1	<0.2	1.7	17	48	103	180	217		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$															
tan δ < 1 < 1 < 1 < 1 < 10403 1 e1/ ϵ_0 < 1.0403 tan δ < 1 < 1 e1/ ϵ_0 < 1 < 1 tan δ < 1 < 1 tan δ < 1 < 1 e1/ ϵ_0 < 1 < 1 tan δ < 1 < 1 < 1 tan δ < 1 < 1 < 1 tan δ < 1 < 1 < 1 < 1 tan δ < 1 < 1 < 1 < 1 tan δ < 1 < 1 < 1 < 1 tan δ < 1 < 1 < 1 < 1 tan δ < 1 < 1 < 1 tan δ < 1 < 1 < 1 < 1 tan δ < 1 < 1 < 1 < 1 tan δ < 1 < 1 < 1 < 1 tan δ < 1 < 1 < 1 < 1 tan δ < 1 < 1 < 1 < 1 tan δ < 1 < 1 < 1 < 1 tan δ < 1 < 1 < 1 < 1 tan δ < 1 < 1 < 1 < 1 tan δ < 1 < 1 < 1 < 1 tan δ < 1 < 1 < 1 < 1 tan δ < 1 < 1 < 1 tan δ < 1 < 1 < 1 tan δ < 1 tan δ < 1 tan δ	osi ^b	e1/e	:	1.(9000	;	!	1	-	1.	00058 1	.00058			
$ e^{i}/\epsilon_{o} - \cdots - 1.0403 - \cdots - 1.0403 - \cdots - 1.0403 - \cdots - 1.0403 + 1.0403$			1 1 1	:	< T	!	!		-	;	< 10	< 10			
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	si		!	1	.0403	;	1	! ! !	!			1.0403			
$ e^{i}/\epsilon_{o} - \cdots - 1.0807 - \cdots - 1.0807 $ tan δ			:	!	< 1	i	:	1 1	;	1 1 1	< 10	< 10			
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	si		:	1 1	,0807	:	-	:	-			1.0807			
$\begin{array}{cccccccccccccccccccccccccccccccccccc$!	;	< 1	!	1 1	!	-	!	< 10	< 10			
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	si		:		1.210		\$ 1 1	:	-		1.210	1.210			
e^{i}/ϵ_{o} 1.563 1.563 1.563 1 1 tan δ < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 < 1 $<$:	;	< 1	1 1 1	!!!!	;	!	!!!	< 10	< 10			-2
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	si		:	1	1,563	:	;	;	:		1.563	1.563			0-
$ e^{i}/\epsilon_{o} - \cdots - 1.857 - \cdots - 1.857 $ $ \tan \delta - \cdots - 1.0030 - \cdots - 1.0030 $ $ e^{i}/\epsilon_{o} - \cdots - \cdots - 1.0030 $ $ \tan \delta - \cdots -$:	1	۸ 1	!	:	!	:	1	< 10	< 10			
$ \tan \delta < 1 < 1 $ $ \epsilon' / \epsilon_0 1,0030 1.0030 $ $ \tan \delta < 1 < 1 $	si		-	-	1.857	!	!	!	!		1.857	1.857			
ϵ'/ϵ_0 1.0030 1.0030 tan δ < 1 < 1 < 10			-	!	< 1	-	1	;	1 1	!	< 10	< 10			
< 1 < 10	4.7 psi		:	1.	0030	1) 	:	}			1.0030			
			!!!	1	\ 1	;	!	-	į	ì	< 10	< 10			

a. Dow-Corning. b. Purified (Air Reduction). c. Olin Mathieson.

II. SUPPLEMENT TO DATA AT ROOM TEMPERATURE A. Materials measured too late for inclusion in Section I

Values of tan δ are multiplied by 10 4 ; frequency given in c/s.

Ceramics		1×10^2	1x10 ³	1x10 ⁴	1×10 ⁵	1x10 ⁶	1×10^7	1x10 ⁸	3x10 ⁸	1x109	$\frac{3\times10^9}{}$	8.6x10
"AFC" Alumina	€' / ﴿	;	!		1 1 1	!	1	!		! ! !		8.28
	o tan 6	1	;	;	!	! ! !	1	1	1		 	9.4
"AlSiMag" 544 ^b	د / و ً	1	!!!	1	1 1	1	1		!	!	! ! !	69.7
(Supercedes previous sample)	tan 6	1		;	!	!	1		.	1 1	! ! !	16
"AlSiMag" 548 dried	€1/€	1	1 1	!	1	1 1 1	!	;	 		:	5.51
	tan 6	1	!	! ! !	1		! ! !	-) 	1	1 1 1	1.0
"AlSiMag" 602 (dried) ^c	€1/€	† ! !	!	1 1	!	! ! !	 - - - -	! ! !	1	1	! ! !	4.62
	tan 6	-	-	!			1	1 1 1	1		1 1	18
"AlSiMag" 652 ^b	€1/€	9.21	9.19	9.18	9.18	9.18	9.18	9.18				
	tan 6	74	11.5	4.2	8		0.15	\ 1				
Beryllium oxide, hot pressed	e 1/e	5.58	5.57	5.55	5.54	5.54	5.54	5.54	1	1	1 .	5.62
(d = 2.560 gm/cc)	tan 6	110	34*	, ,	* ₀		1.3	*8*	!	1	!!!!	10.4
Beryllium oxide, crucible grade	ا جا/ج	-	;	! !	!	[; !	† 	. !	 	1 1	 	3,55
(d = 1.784 gm/cc)	tan 6	-	!		;	;	1	! ! !	1 1	1 1	;	14.9
Coors AI-200 (1956 production)	e¹ /e	-	t 	1	1	1	!	!	;	1		8,63
	tan 6	1	}	1	!		1	;	! ! !	1 1 1.	1	11.6
"Alite" AP-212 ^e	e¹/e	1 1	!		!	 	!	. !		1	1 	8.25
	tan 6	-	!	! !	1	! ! !	1 .1	1 1 1	!	!	:	8.6
"Alite" AP-216 ^e	€1/€	1 1	}	† † !	}		1 1	-	!	:	1 1 1	8.03
	tan 6	1	1 . 1 1	!	:	-	1	!	 - -	1 1	1	13
"Alite" AP-312 ^e	e¹ / e	;	! ! !	1	! !	1	! ! !	:	1	;	1 1	8.42
	tan 6		}.	!	! ! !	!		† † • †	! ! !	1 1	! !	11.5

a. Amer. Feldmuehle. b. Alumina (Amer. Lava). c. Lava (Amer. Lava). d. Beryllium Corp. e. Alumina (U.S. Stoneware). *Mottled sample d = 2.546.

II. SUPPLEMENT TO DATA AT ROOM TEMPERATURE (Cont.)
A. Materials measured too late for inclusion in Section I

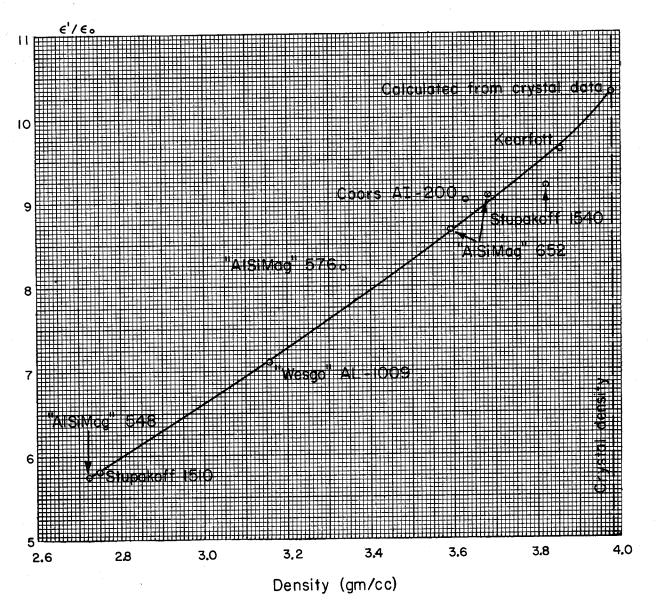
Values of tan δ are multiplied by 10^4 ; frequency given in c/s.

) - C =		t damed breeze in class			
Plastics		$\frac{1\times10^2}{}$	$\frac{1\times10^3}{}$	$\frac{1\times10^4}{1}$	$\overline{1\times10^5}$	1×10^{6}	$\frac{1\times10^7}{1}$	1×10^{8}	$\frac{3\times10^8}{}$	1×10^9	$\frac{3\times10^9}{}$	8, 6×10 ⁹
"Markite" 3985	e' /e	1	*		-	}	!	!	!	}	!	40
	tan 6		!	*400	> 20*	> 10*	* 09 <	;	!	:	:	3.0
	ی	(ohm-cm)		1.73	1.73	1.73	1.73	-	!		1 1	1.7
"Markite" 12812	<i>د ا</i> /د	!	1	1	:	1 1	1200	1	1	!	!	21
	tan 6	!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!	-	>105*	-	!	ე.* ^	!	1	1		1.5
	٥	(ohm-cm)	!	16.4	16.4	16.0	15.8	! ! !	!	1	1 1 1	9.9
"Scotchply" 1002, isotropic	ει /ε ⁰	!	1	! ! !	!!!	1 1 1		!	4.56	4.53	4.51	4.48
	tan 6	; ; [}	!	!	! !	-		158	162	167	175
"Scotchply" 1002, crossply	e! /e	:	1	!	1	: !		!	4.42	4.40	4.39	4.38
,	tan ô	1	;	-	!	-	!	1 1 1	164	177	186	200
"Scotchply" 1002, unidirectional	, e'/e	1	;	! ! !	-	:	1	1 1	4,35	4.32	4.28	4.24
Ļ	tan 6		}	:		! ! !	!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!	1	171	171	172	173
"Scotchply" XPM-107	د، /د	!!!!	;	1	1 1 1	-		!	4.31	4.30	4.29	4.28
	tan 6		!		!	:	1		129	162	181	202

a. Polyester "fiberglas" laminate (Minn. Mining) b. Epoxy - "fiberglas" laminate (Minn. Mining). * tan δ not mulitplied by 10 4 .

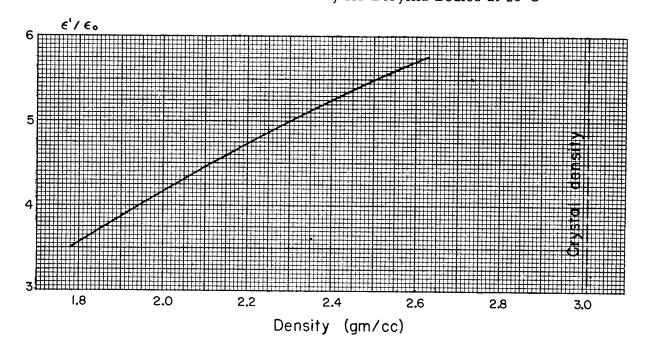
II B.

Dielectric Constant vs. Density for High Alumina Bodies at 26°C

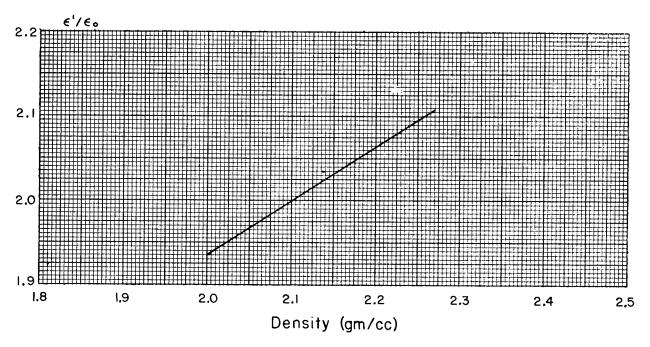


II B.

Dielectric Constant vs. Density for Beryllia Bodies at 26°C



Dielectric Constant vs. Density for "Teflon" at 26°C



III. Data at Fixed Frequencies as a Function of Temperature

Previous to this volume of the "Tables," the highest temperature of measurements has not exceeded, with few exceptions, the long-time thermal stability temperature for each material.

In the present volume, data have been taken on several laminates at temperatures above normal, For these, the time intervals of measurement are indicated. The samples were measured in partial vacuum in order to withdraw gaseous decomposition products.

Other curves showing data with increasing and decreasing temperatures, particularly with ceramics, indicate changes due to water loss since the sample is not in equilibrium with room humidity at the end of the run. The change in electrical properties with water loss is a reversible process more easily demonstrated in the microwave region, where it is mainly a volume effect, than at low frequencies where it is mainly a surface effect.

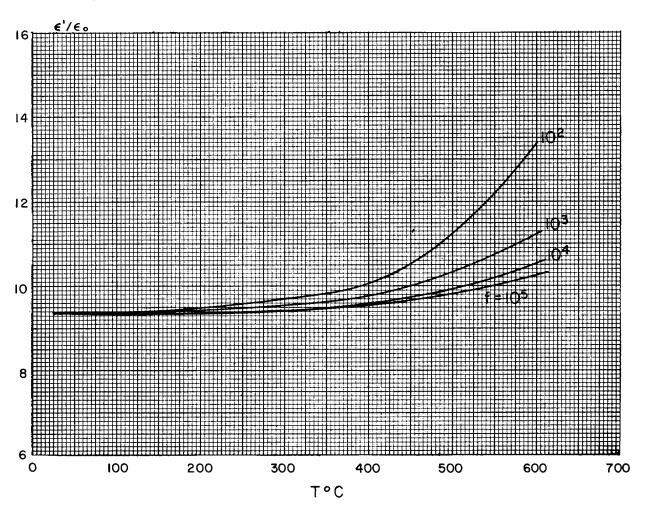
As in the room temperature measurements, the electric field direction is perpendicular to the plane of laminates for frequencies in the range 10^2 through 3×10^8 c/s; it is parallel to or in the plane of the laminate for all higher frequencies unless otherwise specified.

The measuring frequency for the curves marked $f = 10^{10}$ was 8.5 kMc.

III A 1. Crystals

Aluminum oxide crystal, sapphire Field perpendicular to optical axis

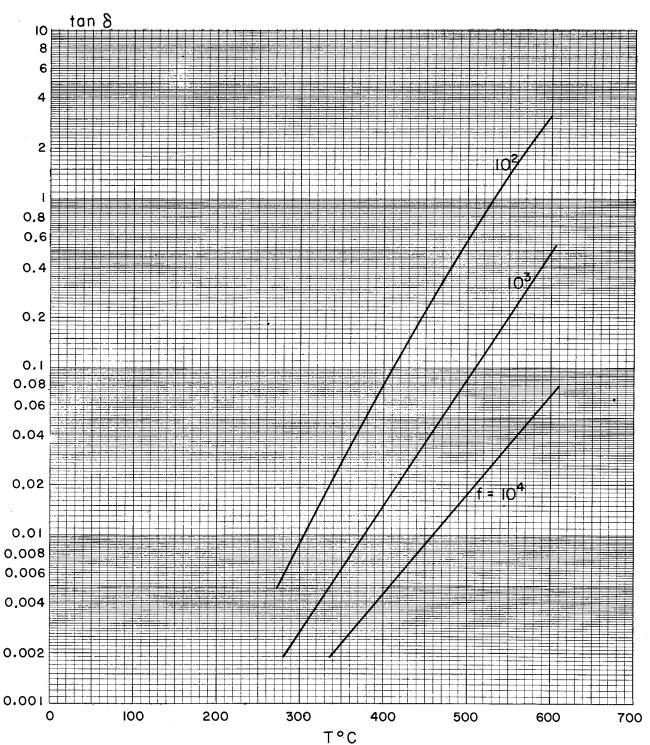
Linde Air



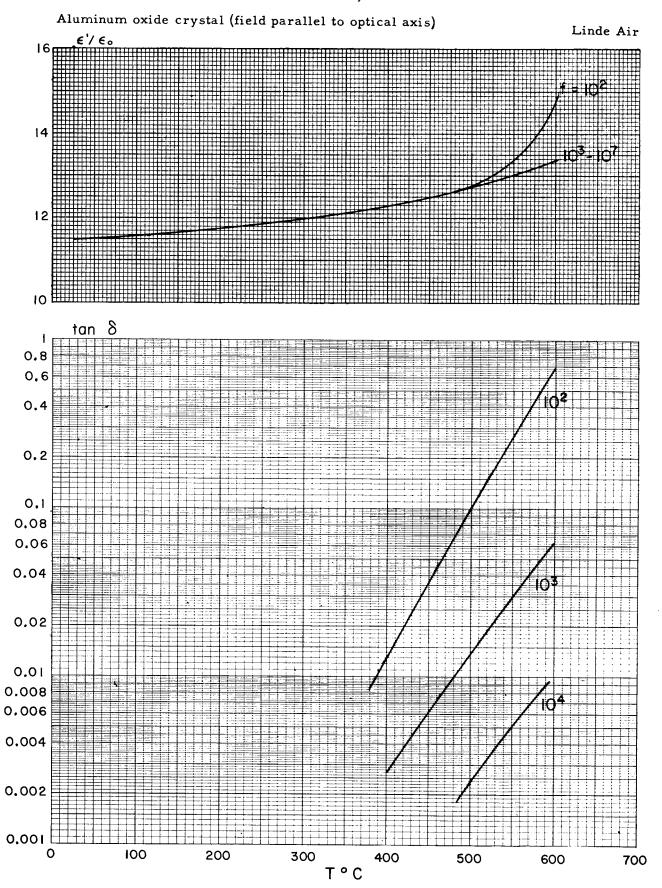
III A 1. Crystals

Aluminum oxide crystal, sapphire Field perpendicular to optical axis

Linde Air



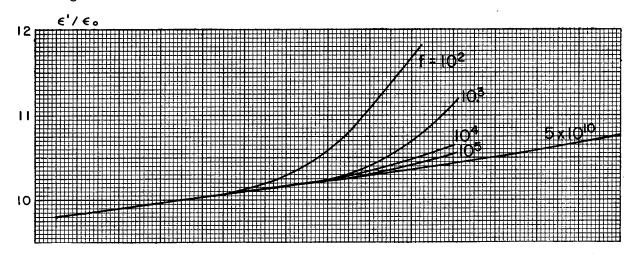
III A 1. Crystals

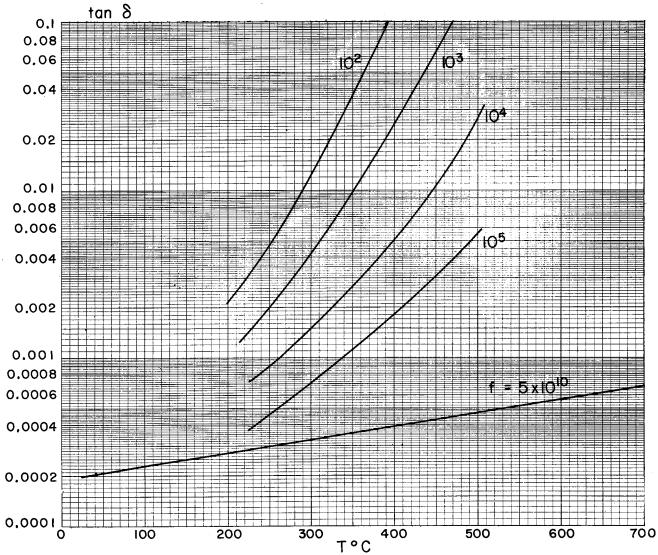


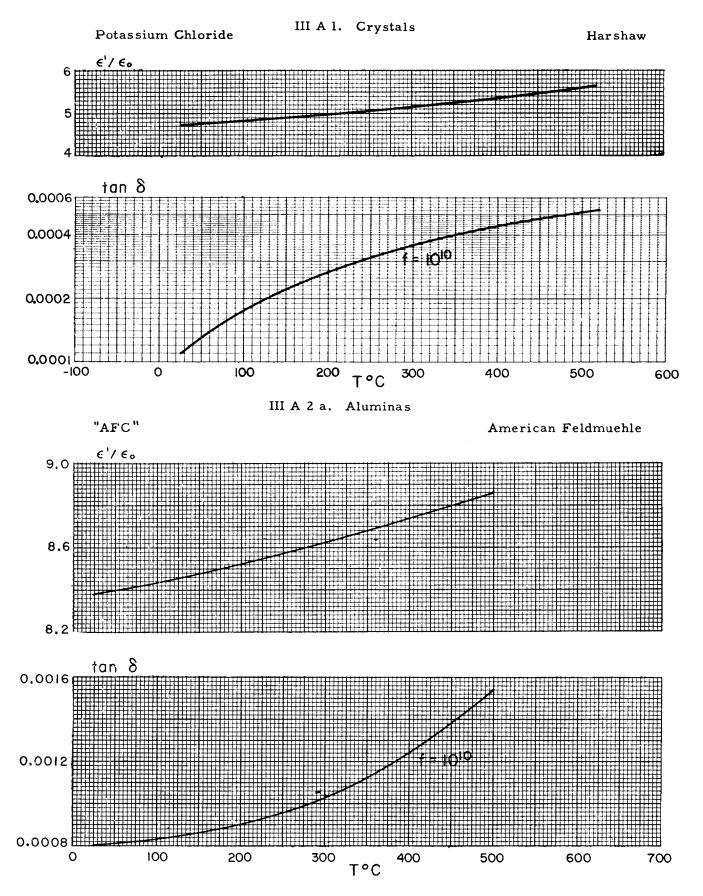
III A 1. Crystals

Magnesium oxide crystal

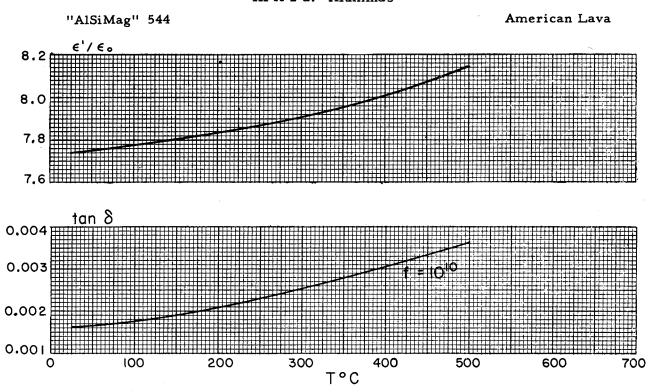
Norton

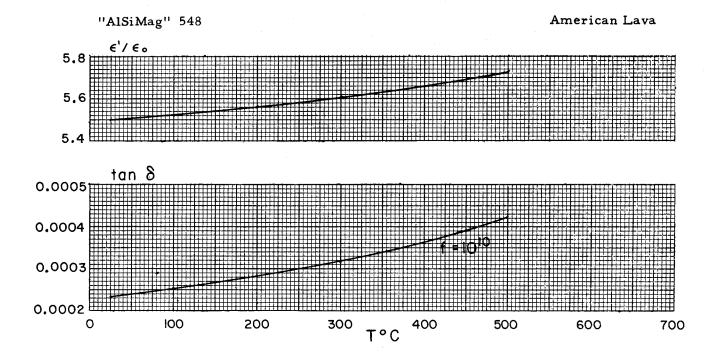






III A 2 a. Aluminas

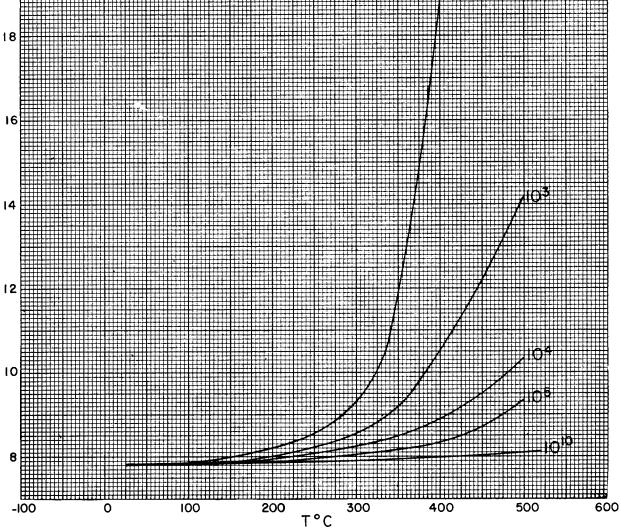




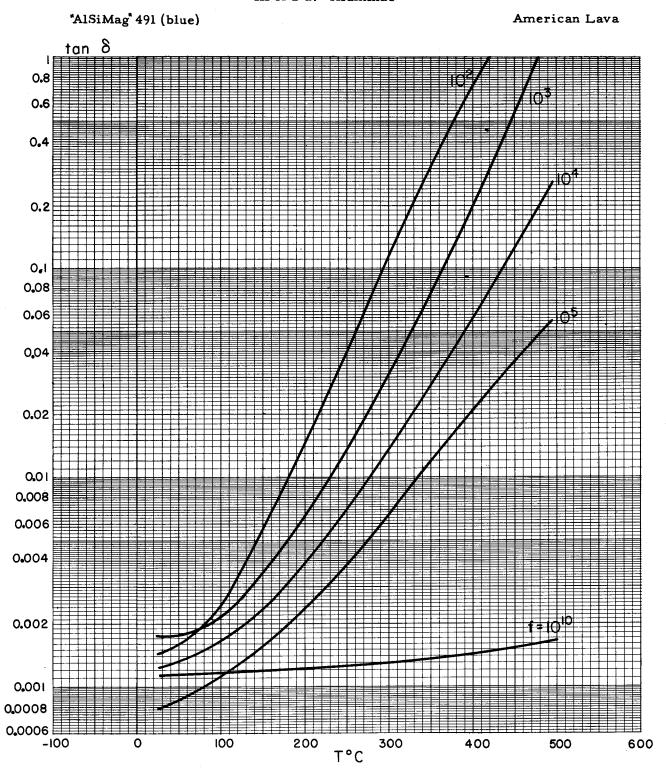
III A 2 a. Aluminas

American Lava

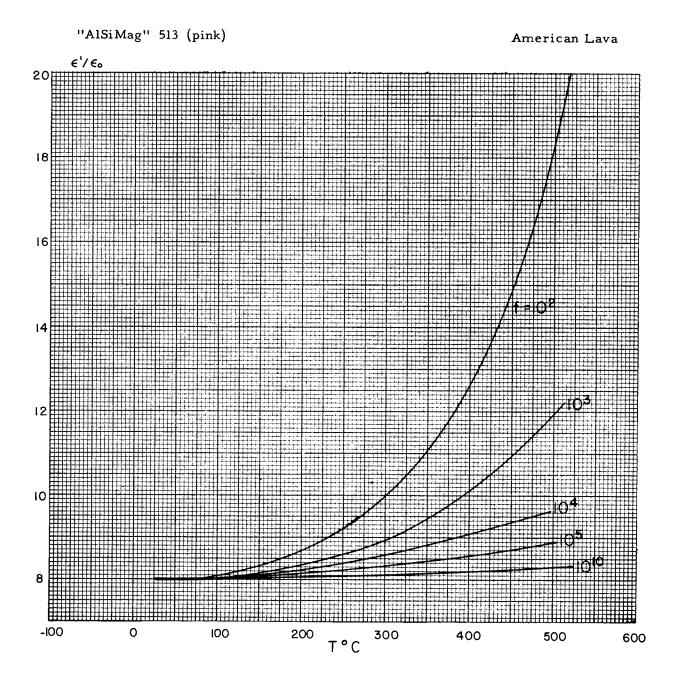
"AlSiMag" 491 (blue) €' / €₀ 20 18



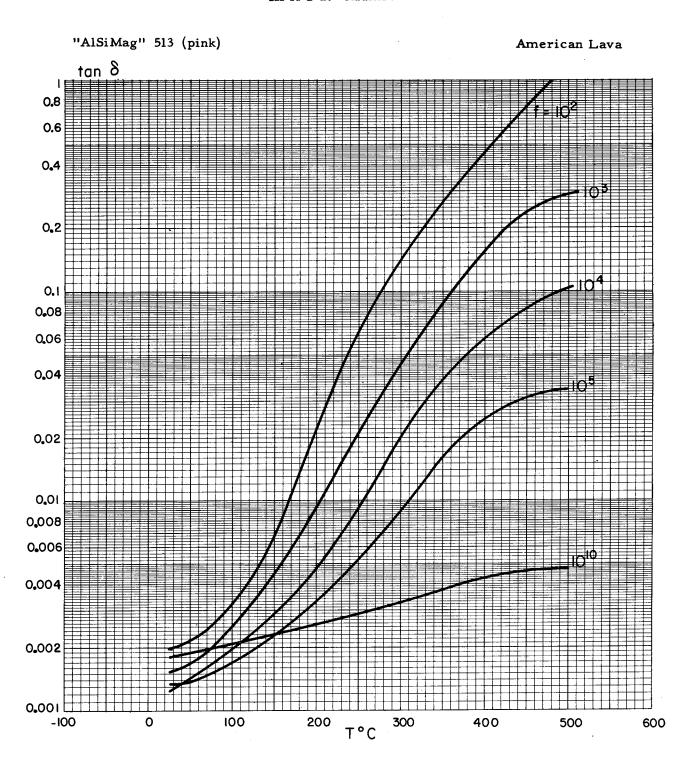
III A 2 a. Aluminas



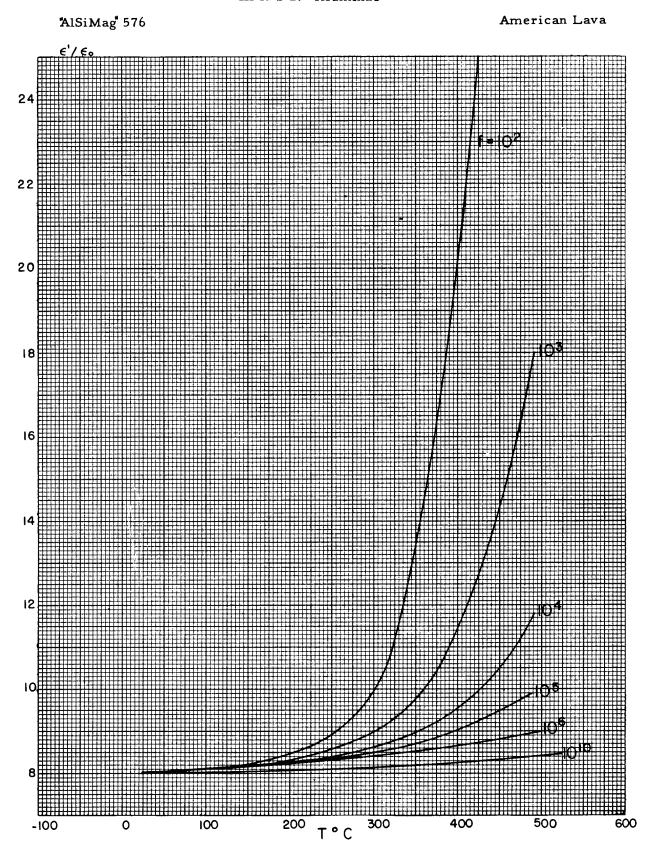
III A 2 a. Aluminas



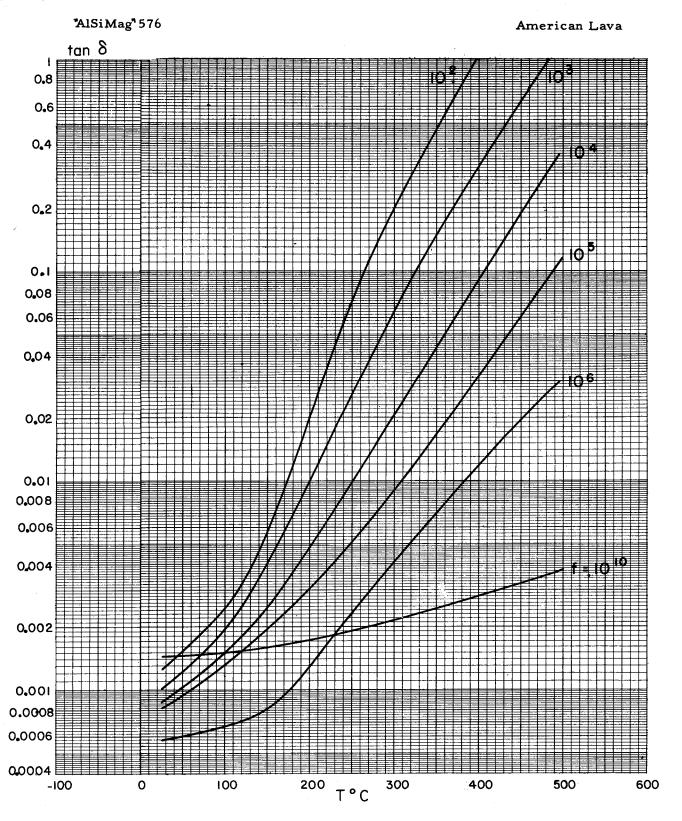
III A 2 a. Aluminas



III A 2 a. Aluminas



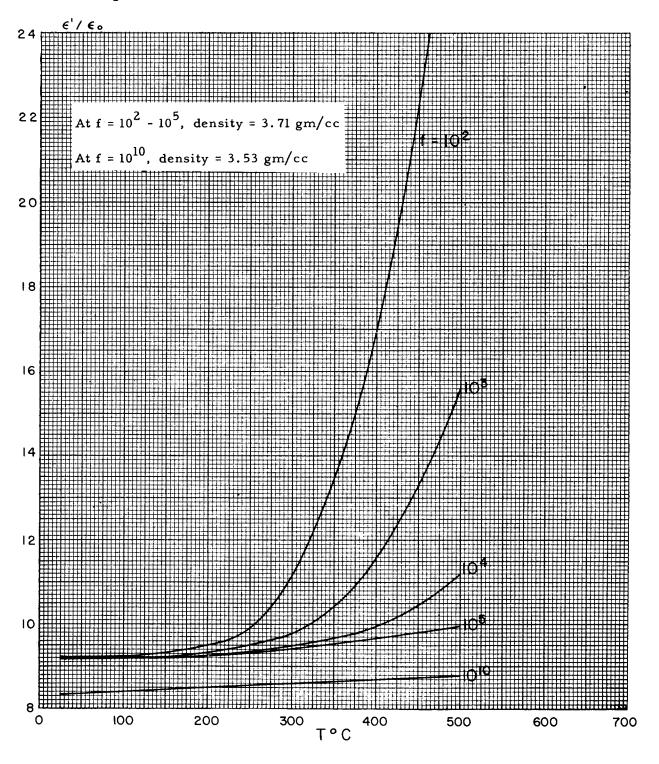
III A 2 a. Aluminas



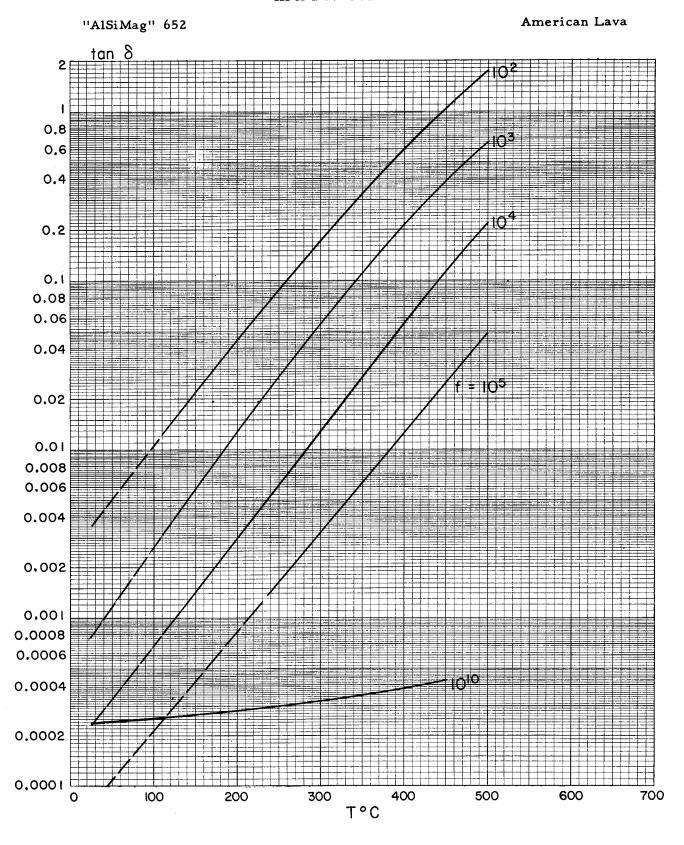
III A 2 a Aluminas

"AlSiMag" 652

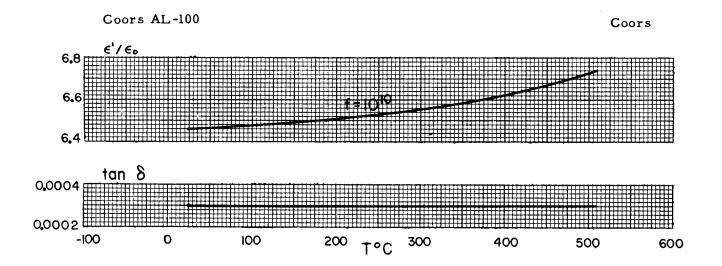
American Lava

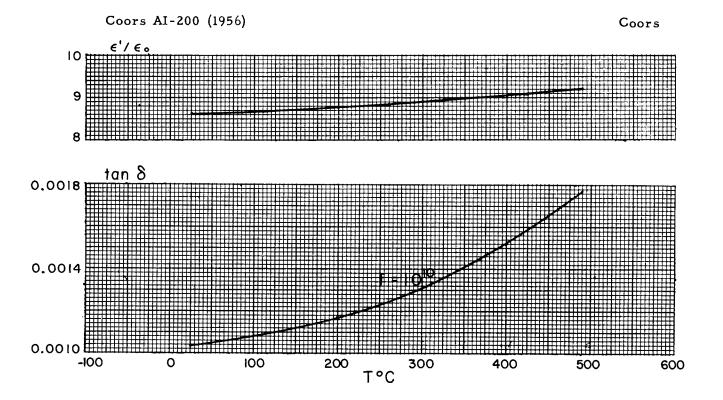


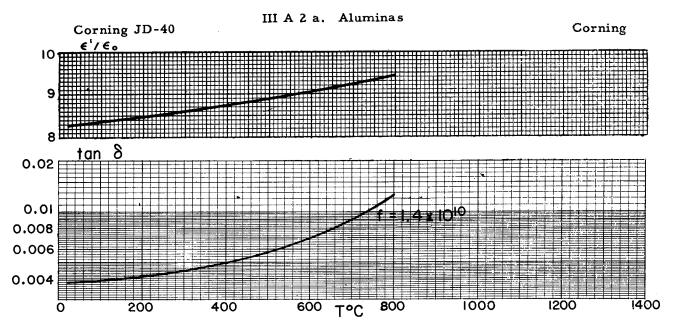
III A 2 a. Aluminas

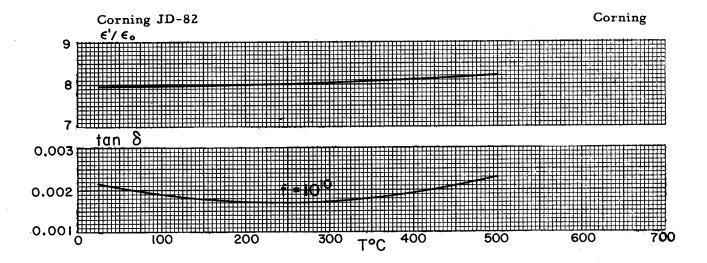


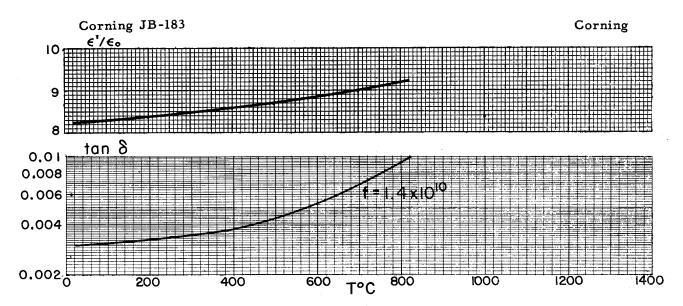
III A 2 a. Aluminas



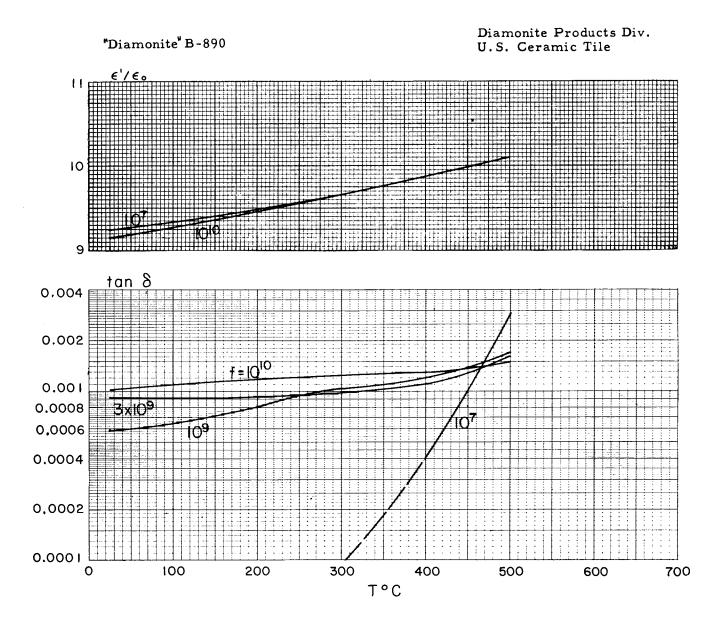




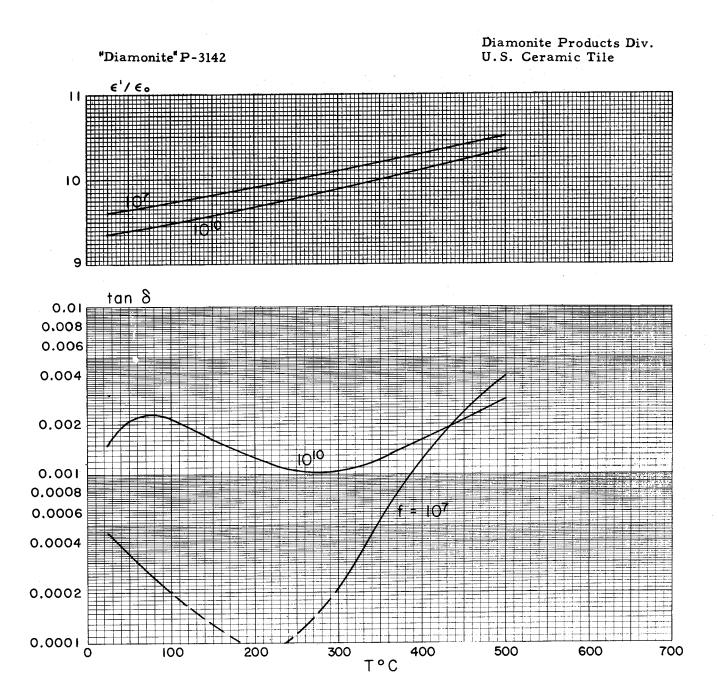




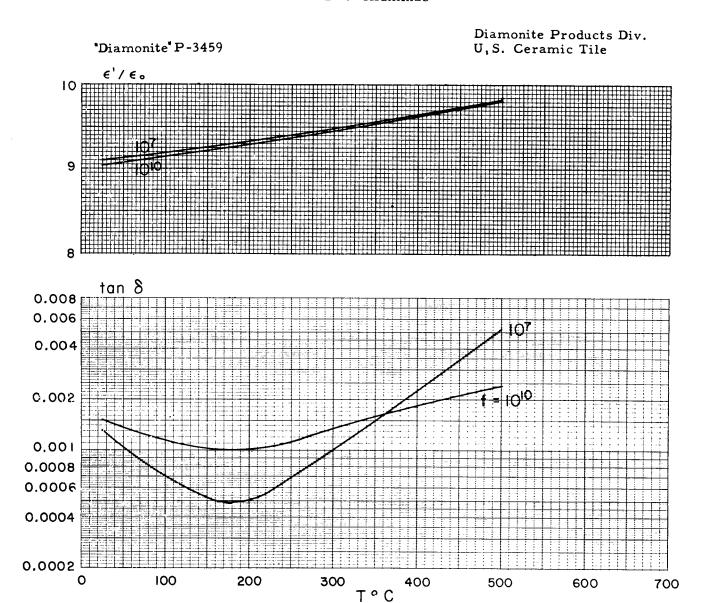
III A 2 a. Aluminas



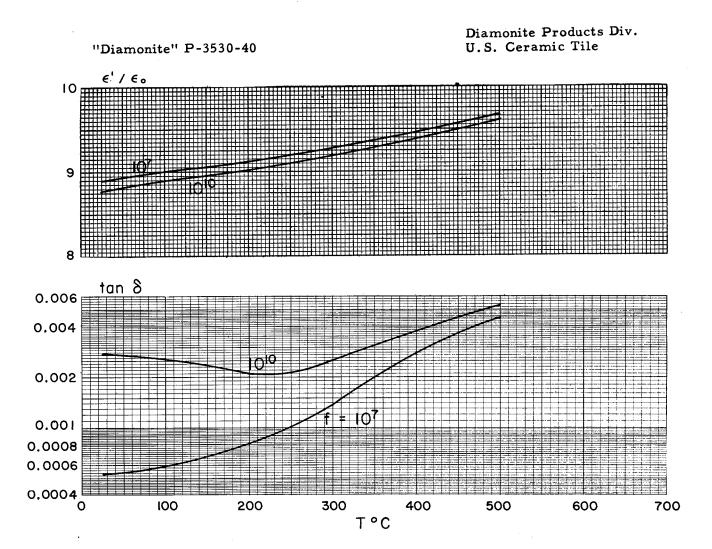
III A 2 a. Aluminas



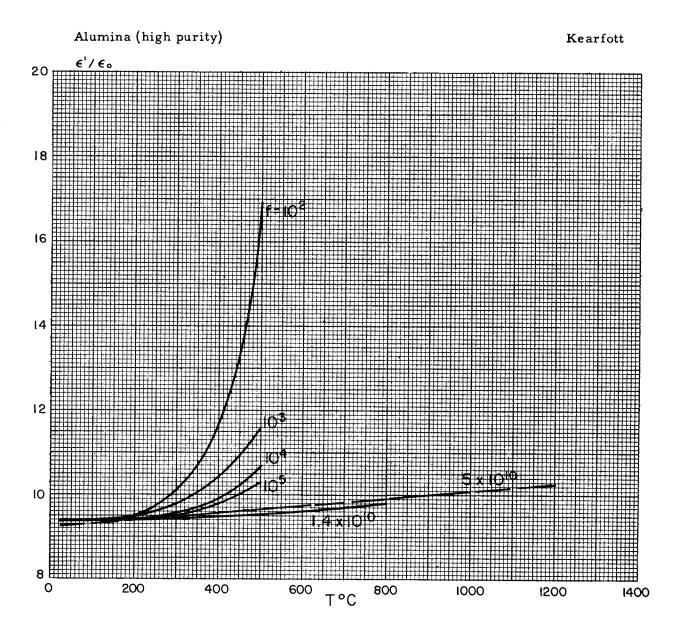
III A 2 a. Aluminas



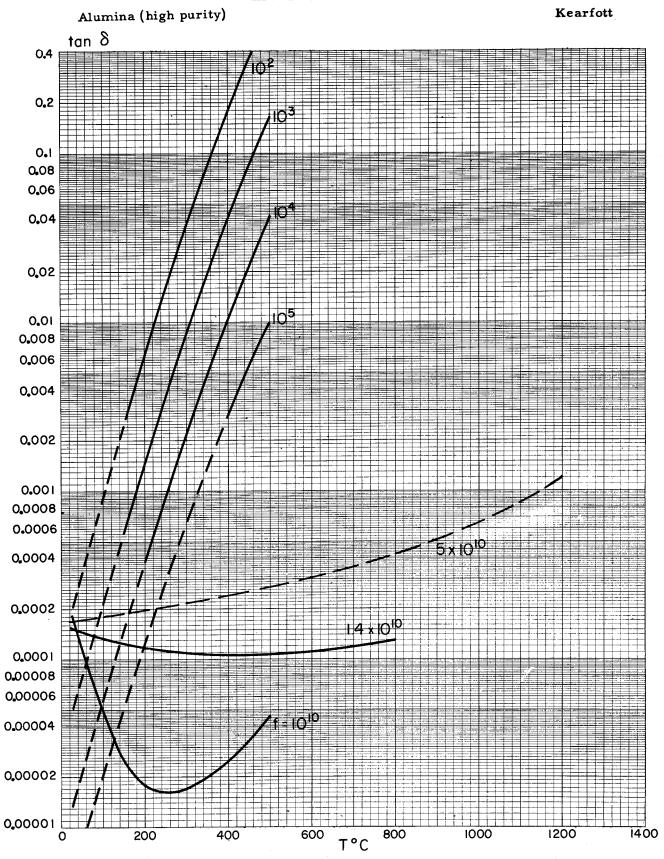
III A 2 a. Aluminas



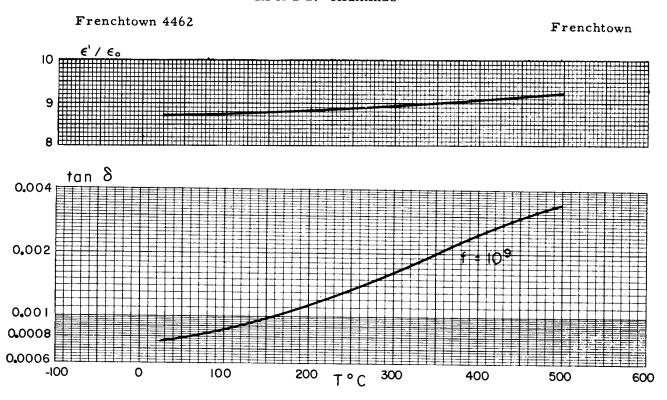
III A 2 a. Aluminas

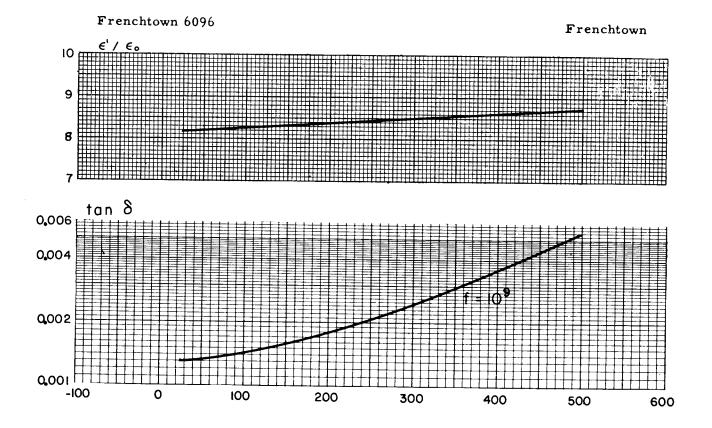


III A 2 a. Aluminas

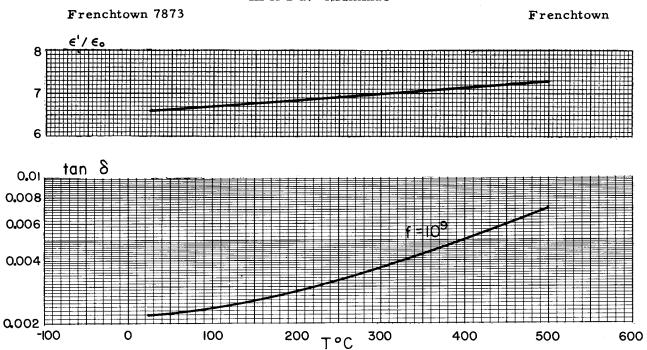


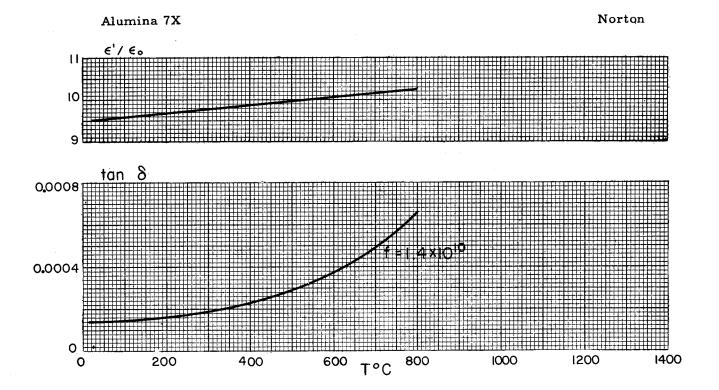
III A 2 a. Aluminas



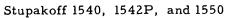


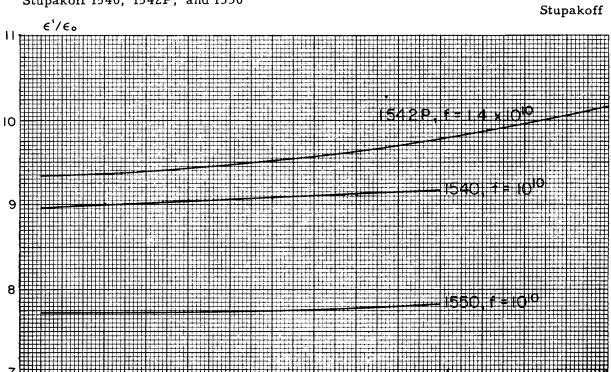
III A 2 a. Aluminas

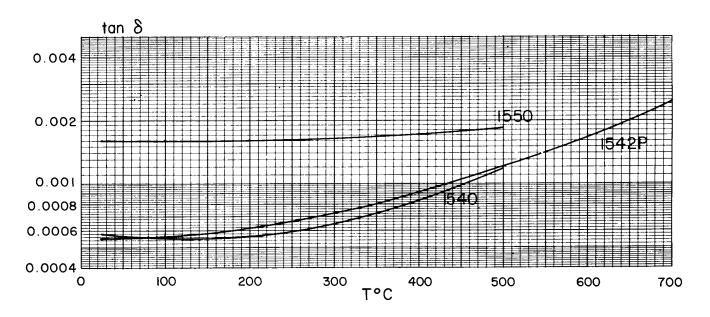




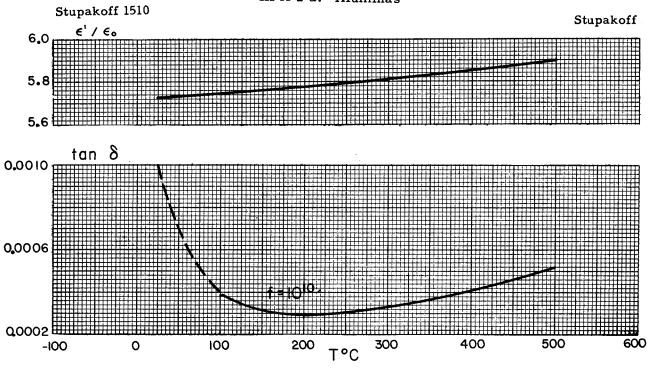
III A 2 a. Aluminas





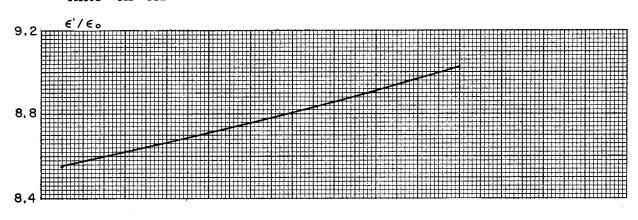


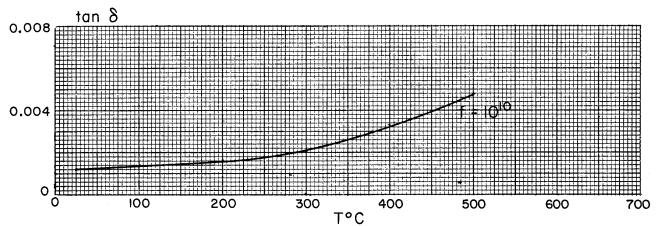
III A 2 a. Aluminas

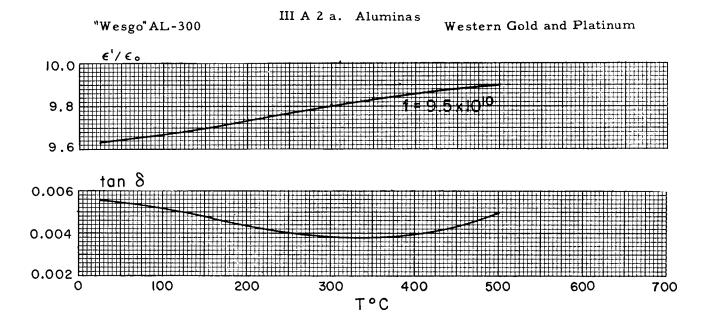


"Alite" AP 312

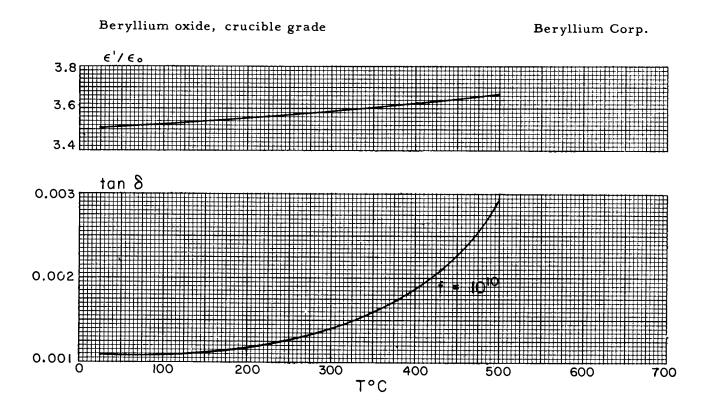
U.S. Stoneware







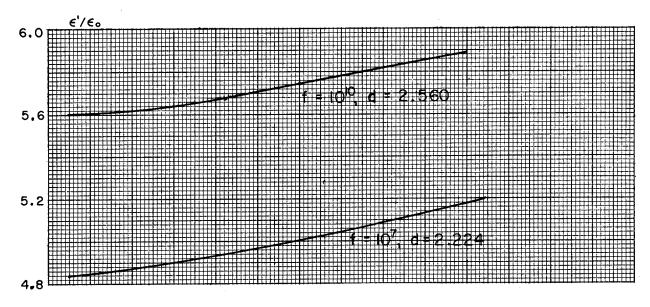
III A 2 b. Beryllias

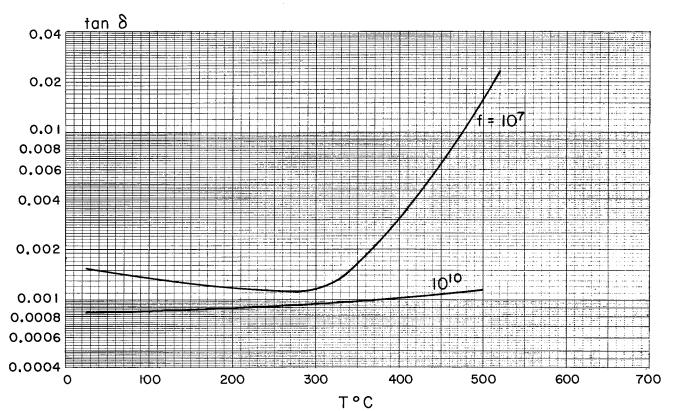


III A 2 b. Beryllias

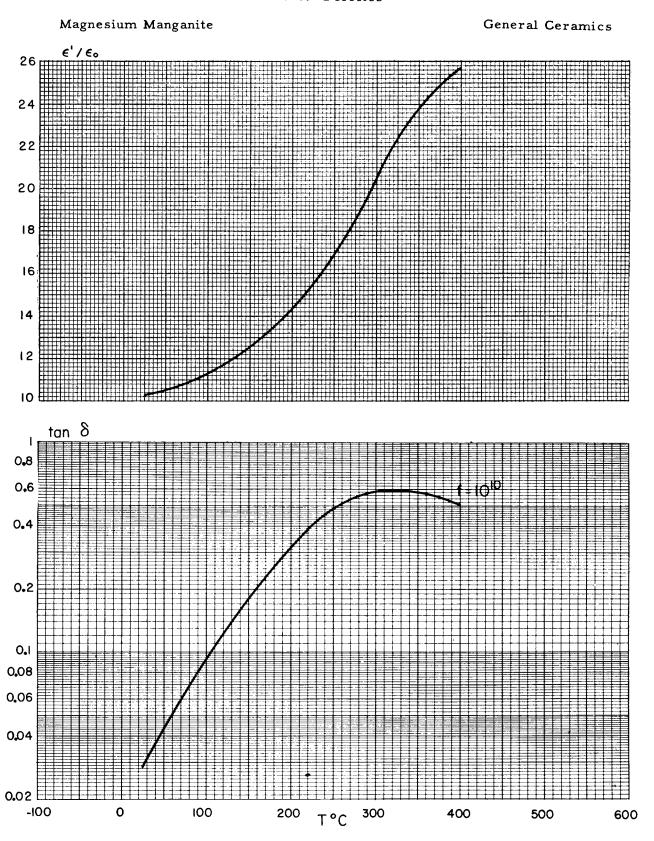
Beryllium oxide, hot pressed

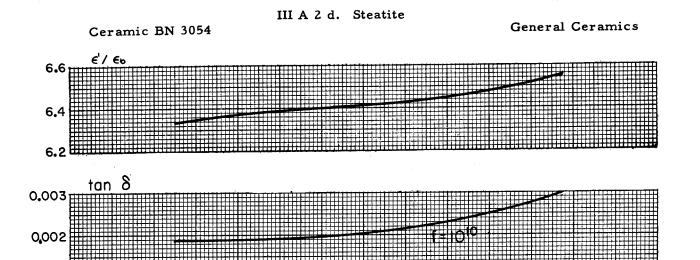
Beryllium Corp.





III A 2 c. Ferrites





T°C

100

300

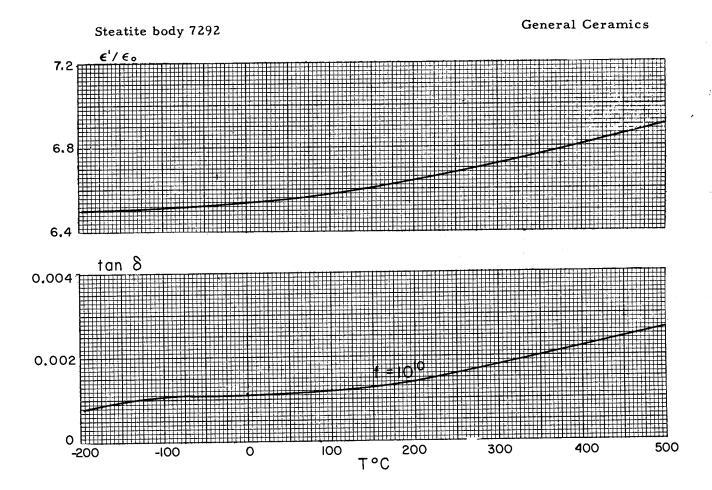
600

500

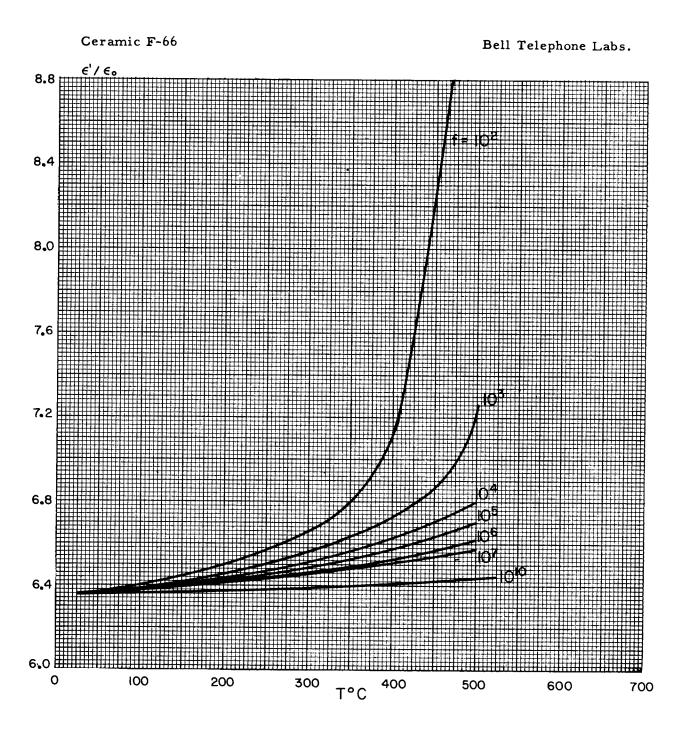
400

0,001

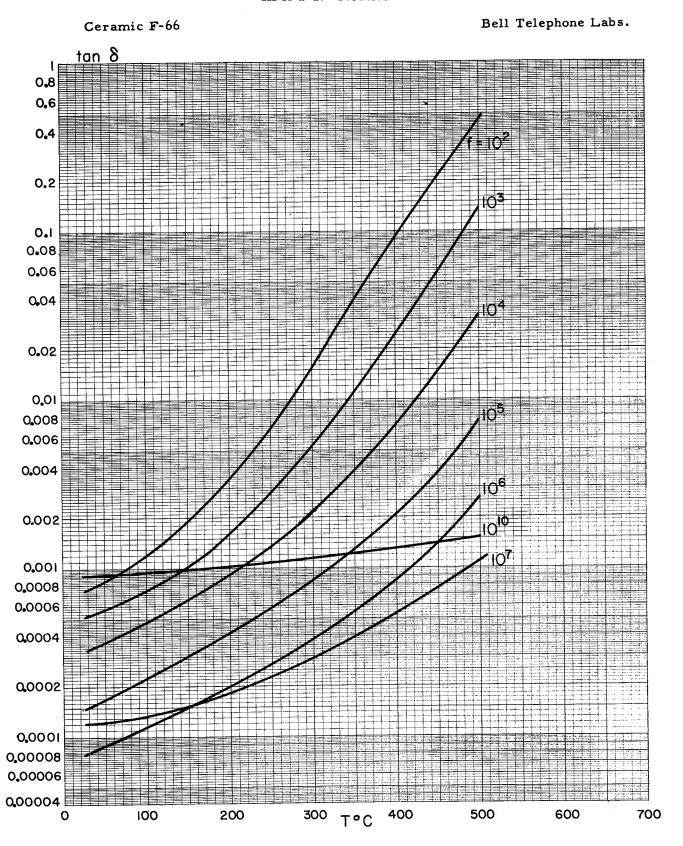
-100



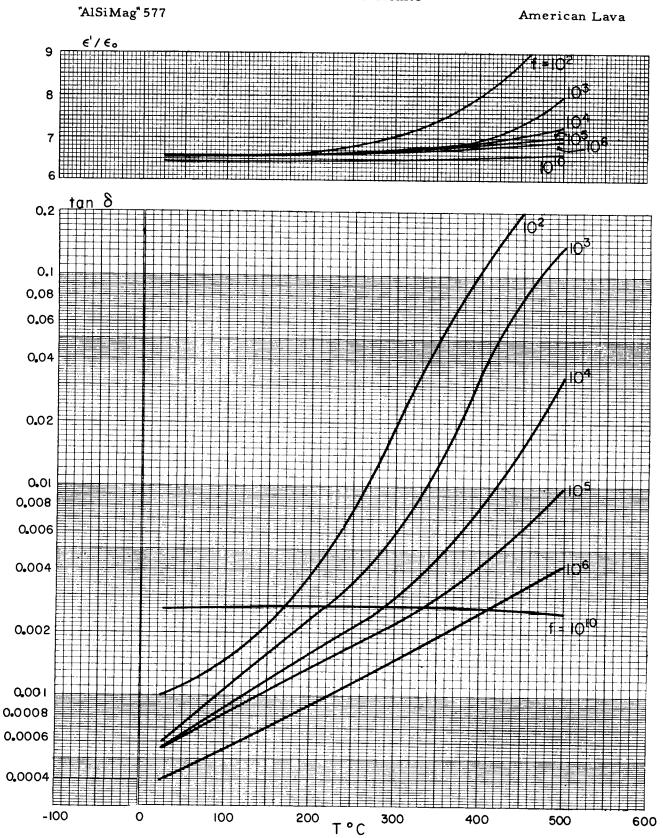
III A 2 d. Steatite



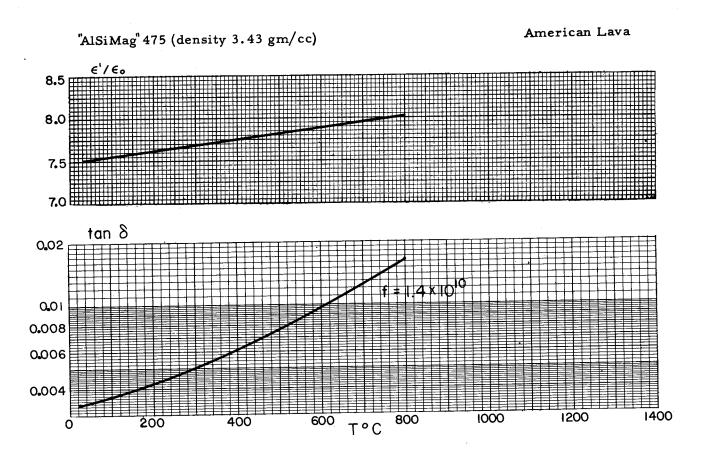
III A 2 d. Steatite



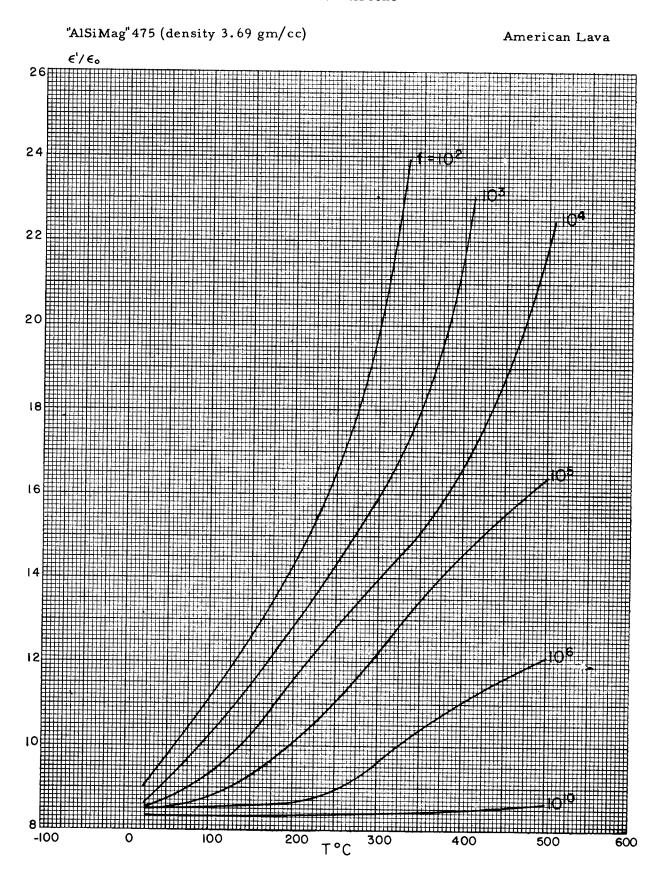
III A 2 e. Wollastonite



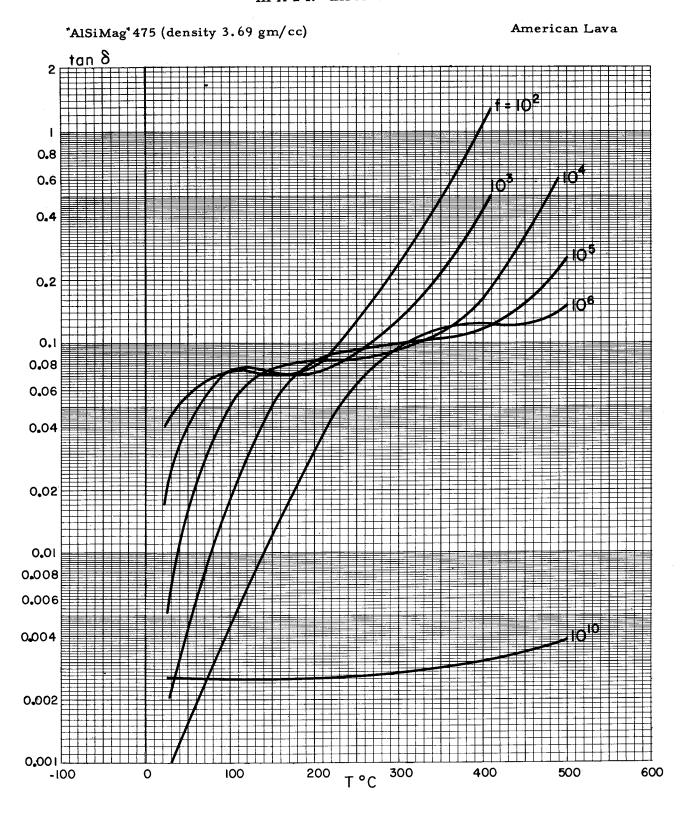
III A 2 f. Zircons



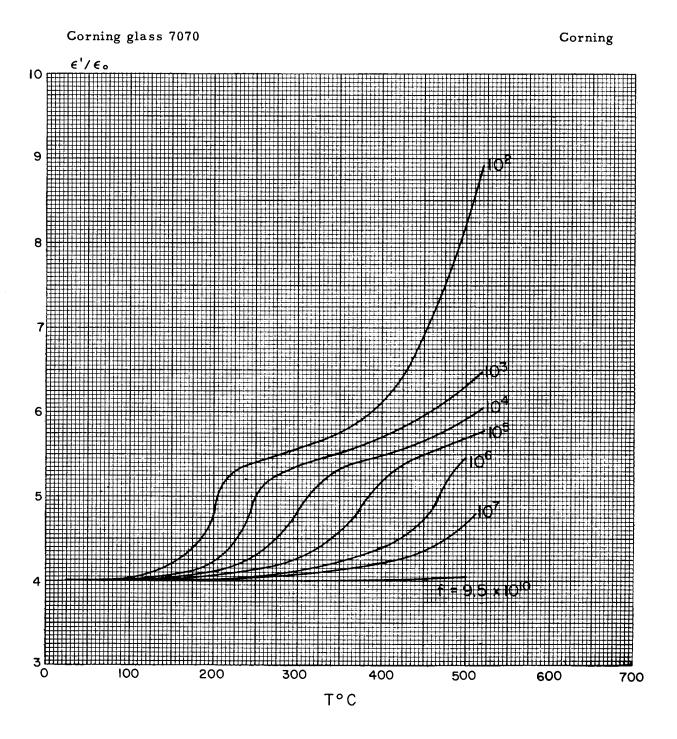
III A 2 f. Zircons



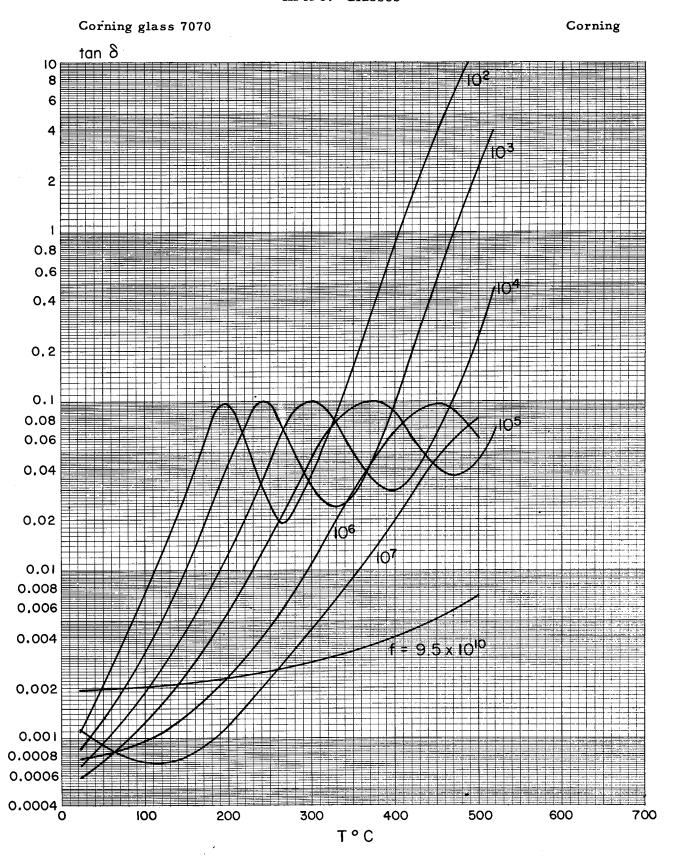
III A 2 f. Zircons



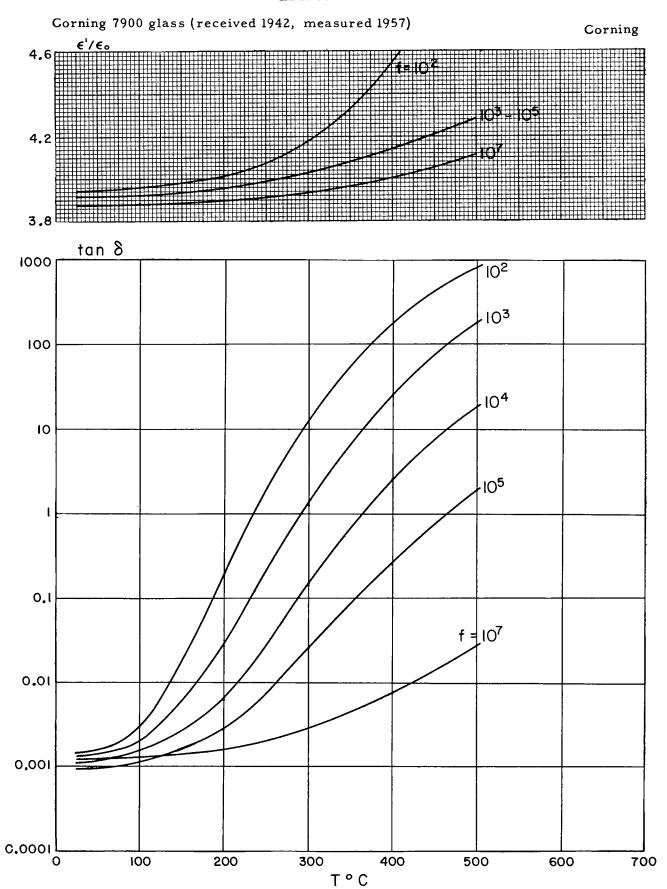
III A 3. Glasses



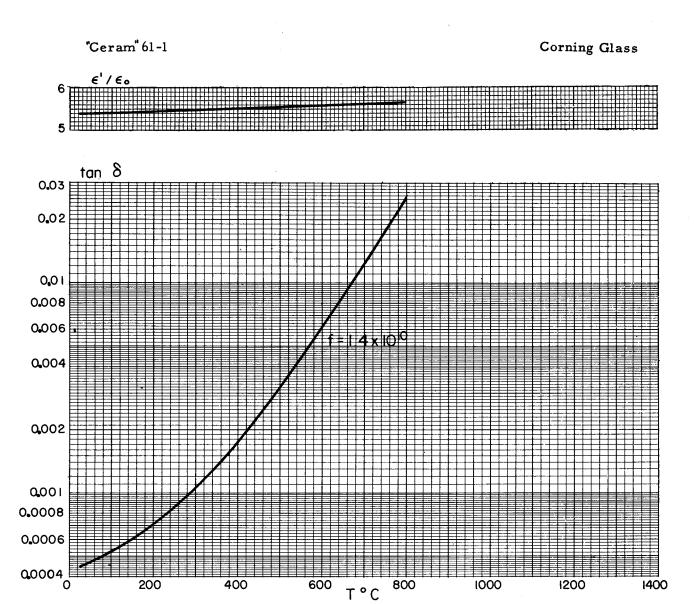
III A 3. Glasses



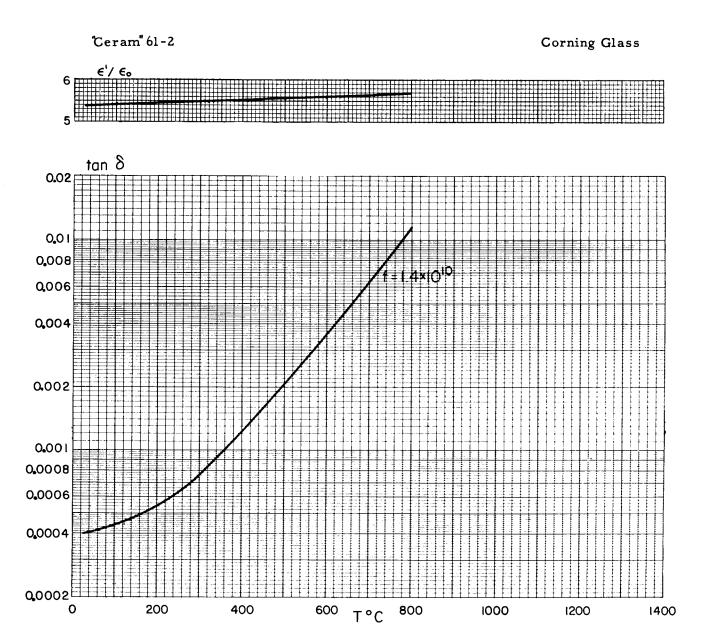
- 64 -III A 3. Glasses



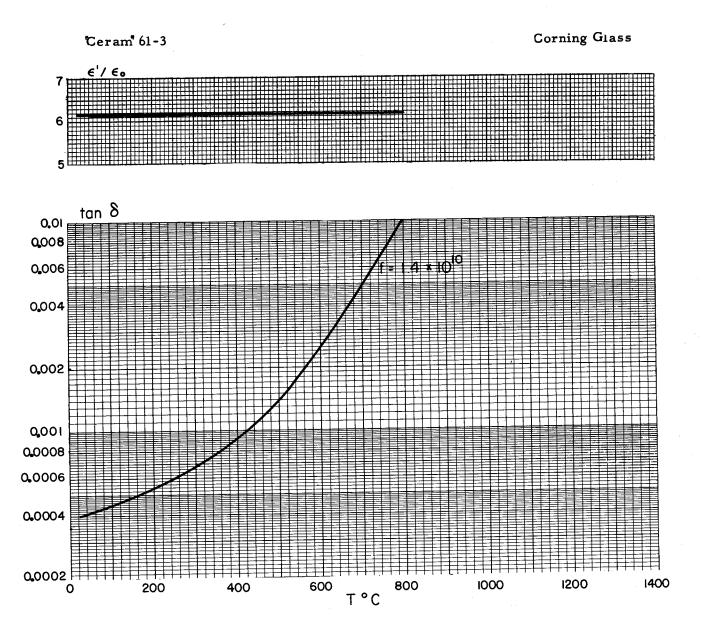
III A 3. Glasses



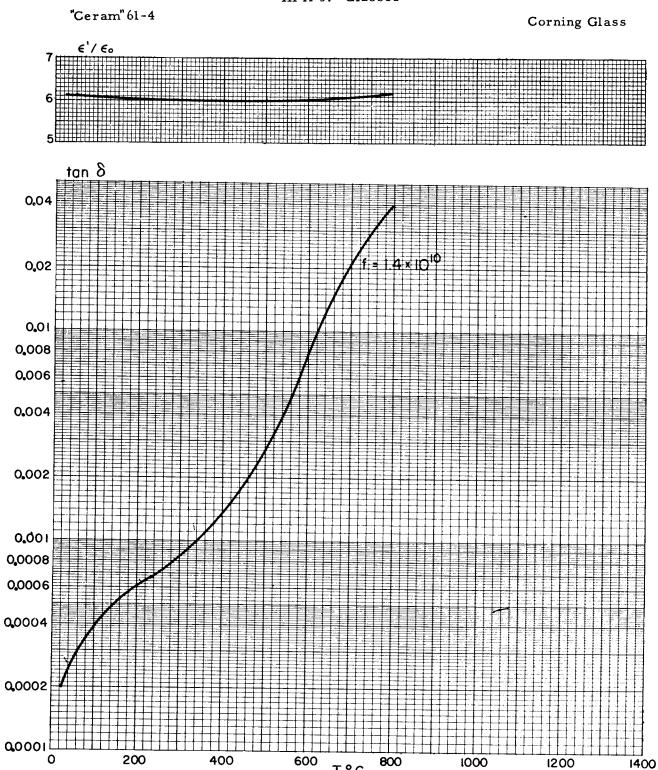
III A 3. Glasses



III A 3. Glasses



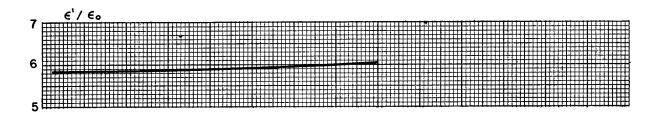
III A 3. Glasses

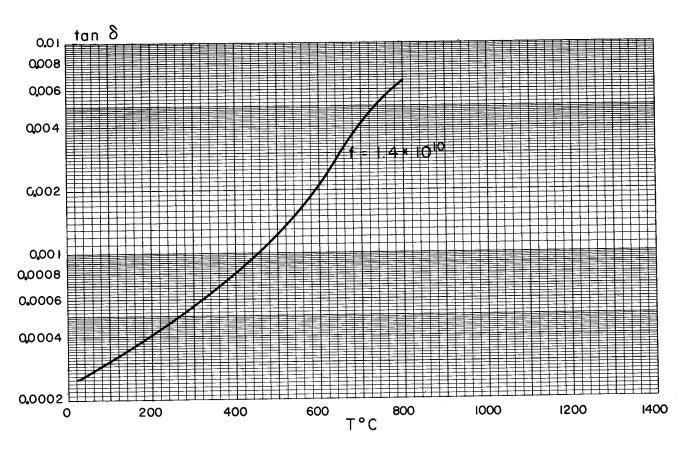


III A 3. Glasses

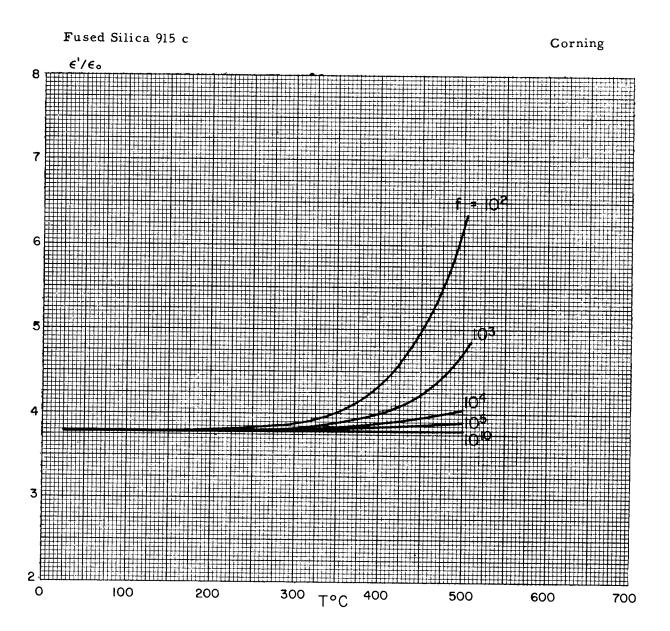


Corning Glass

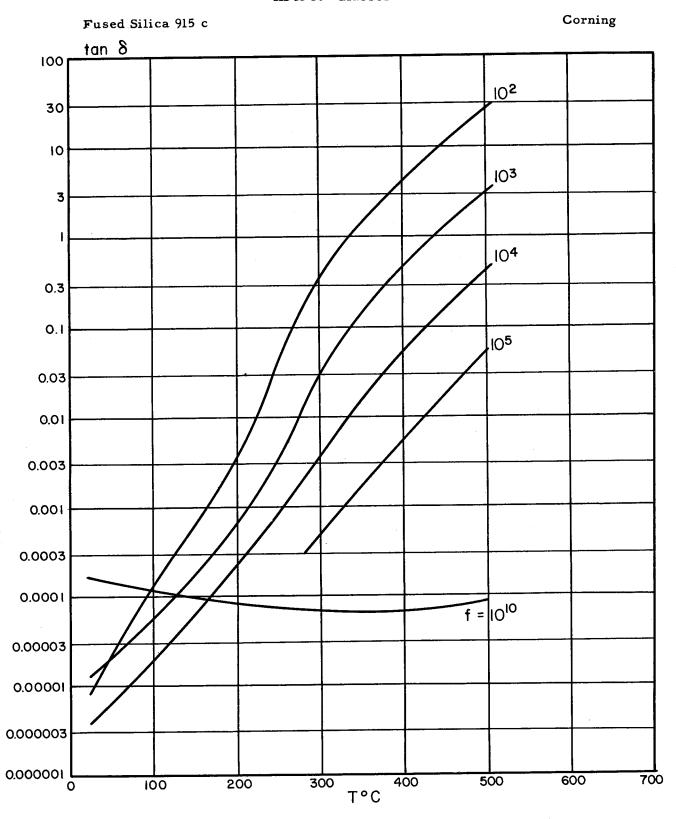




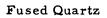
III A 3. Glasses



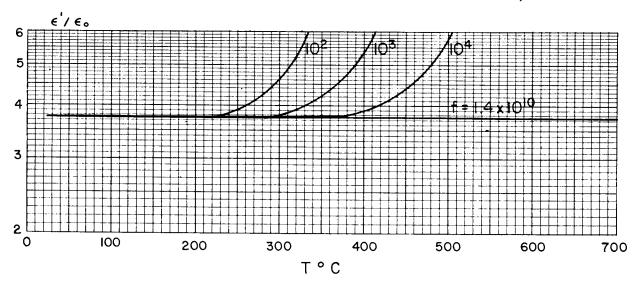
III A 3. Glasses



III A 3. Glasses

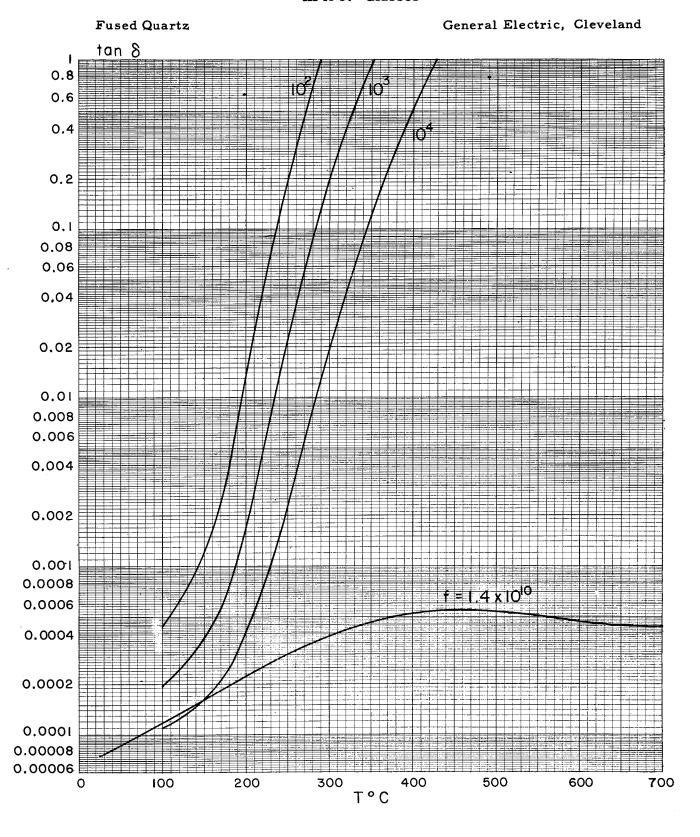


General Electric, Cleveland

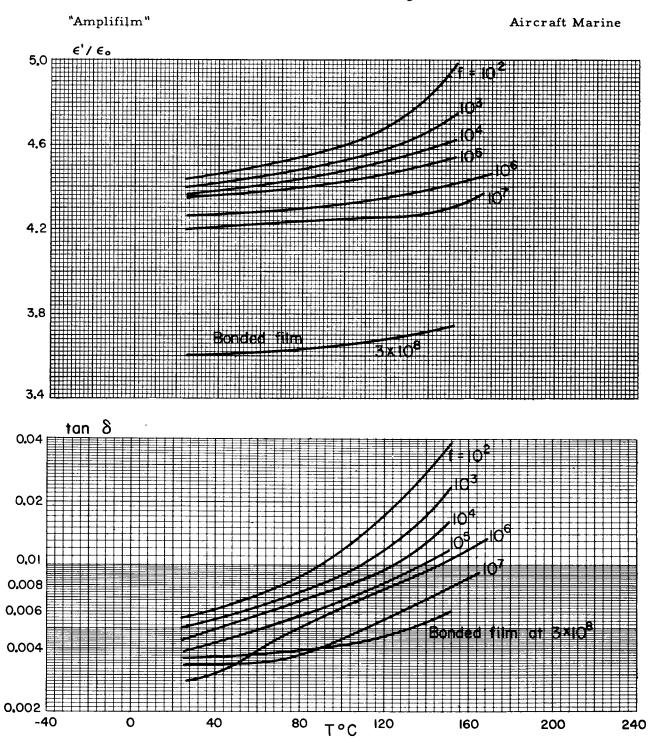


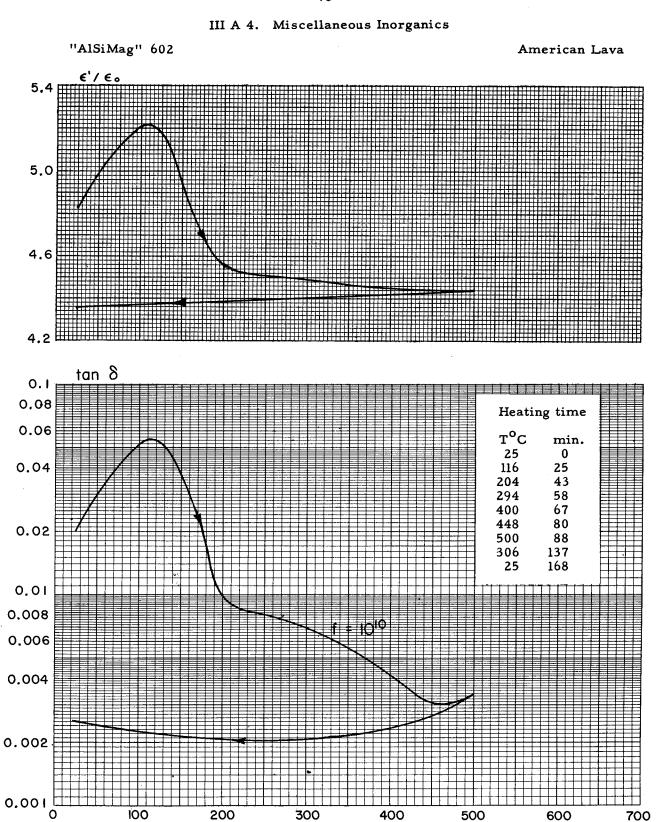
At 800° C, 1.4×10^{10} cycles, $\epsilon'/\epsilon_{o} = 3.76$ and $\tan \delta = 0.00048$. At 1200° C, 5×10^{10} cycles, $\epsilon'/\epsilon_{o} = 3.8-3.9$ and $\tan \delta < 0.002$.

III A 3. Glasses



III A 4. Miscellaneous Inorganics



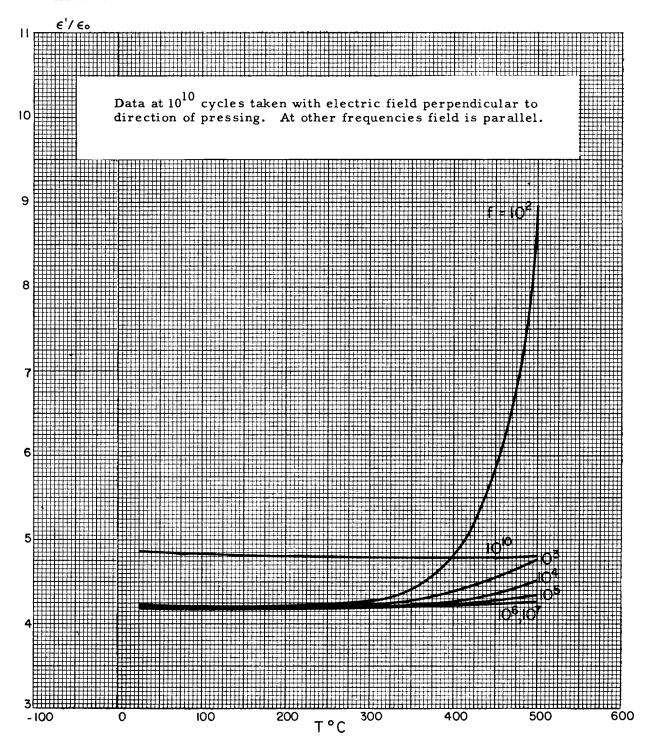


T°C

III A 4. Miscellaneous Inorganics

Hot Pressed Boron Nitride

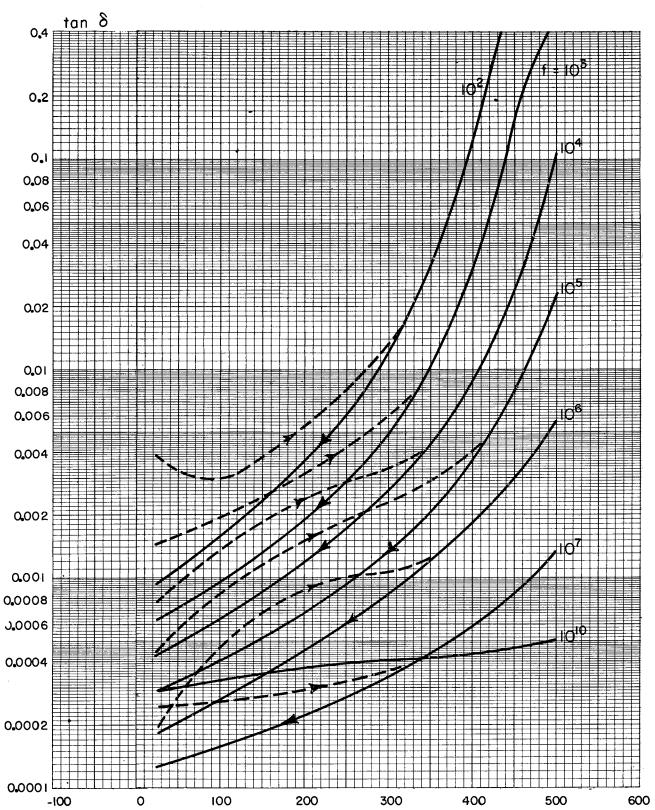
Carborundum Co.



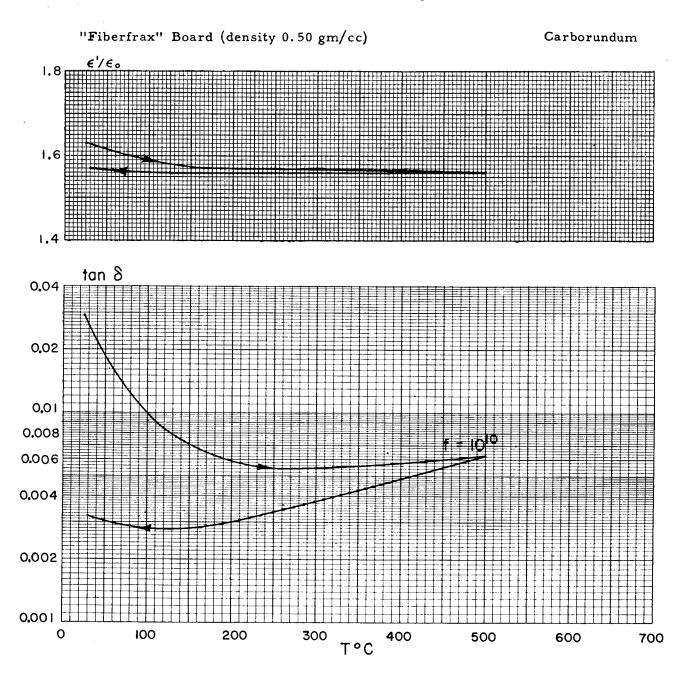
III A 4. Miscellaneous Inorganics

Hot Pressed Boron Nitride

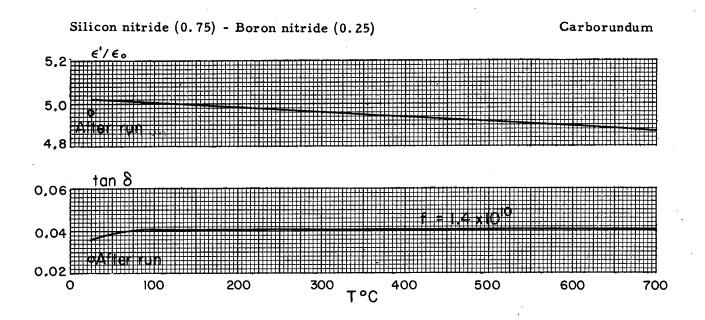
Carborundum Co.

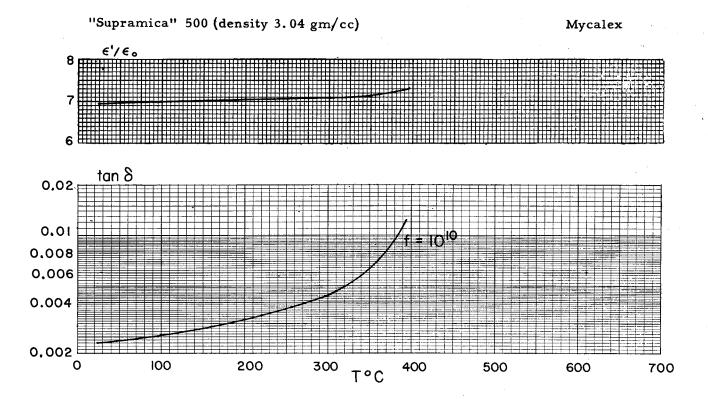


III A 4. Miscellaneous Inorganics

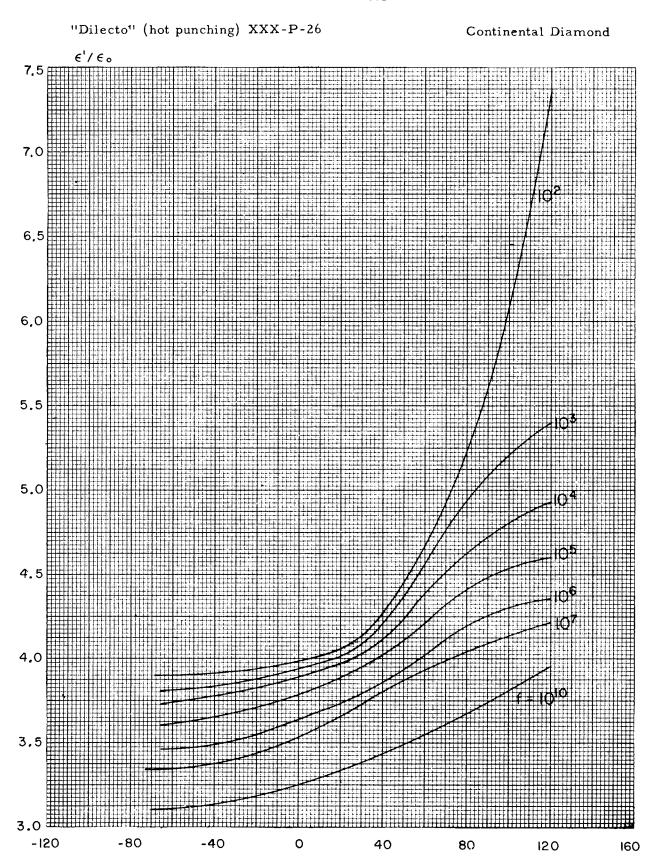


III A 4. Miscellaneous Inorganics

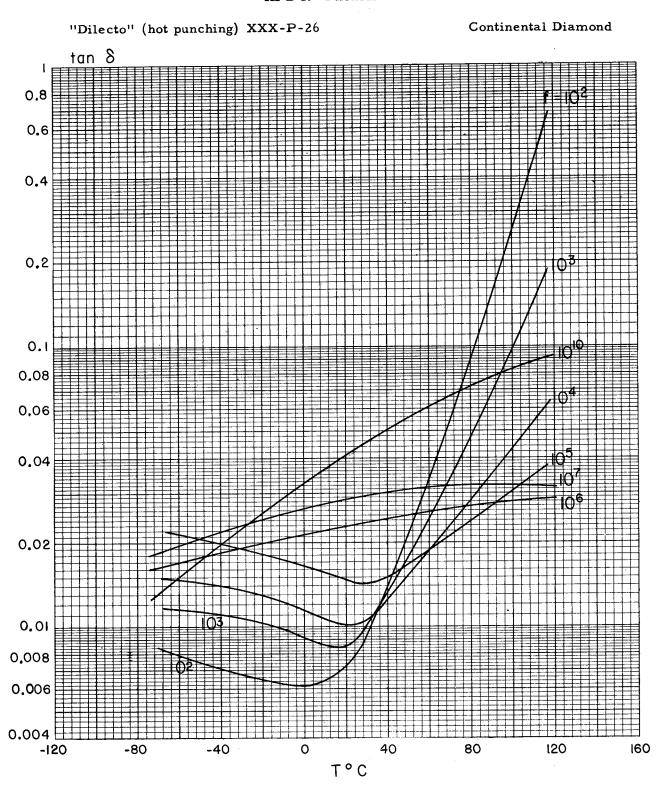




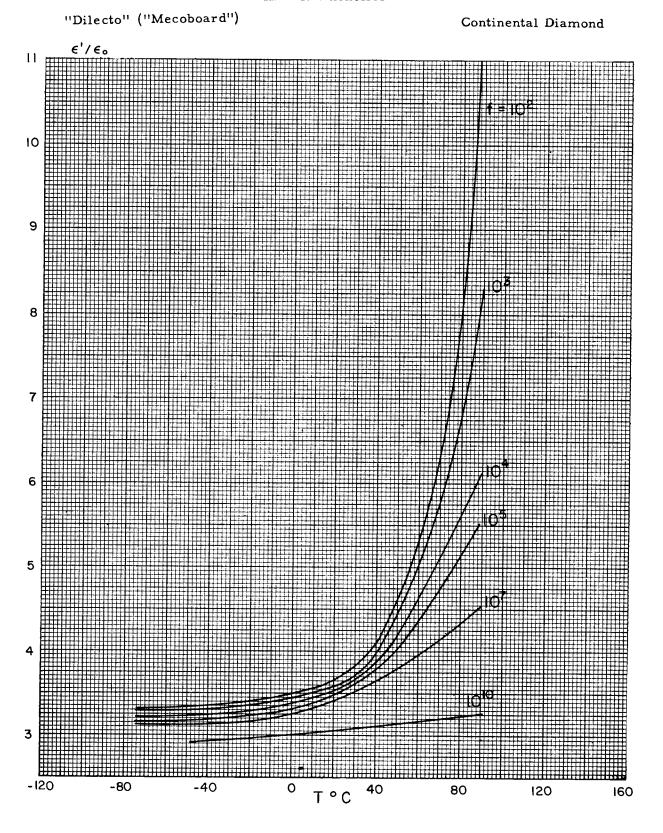
III B 1. Phenolics



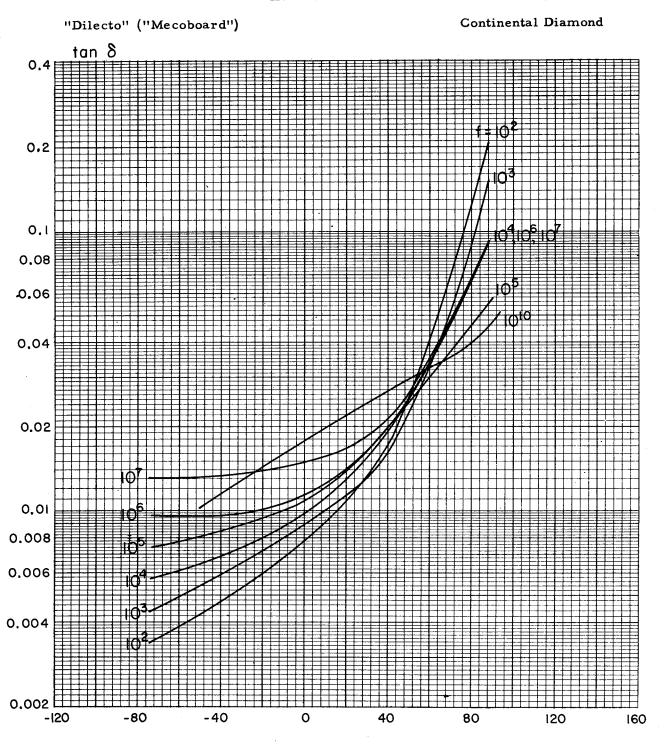
III B 1. Phenolics



III B 1. Phenolics



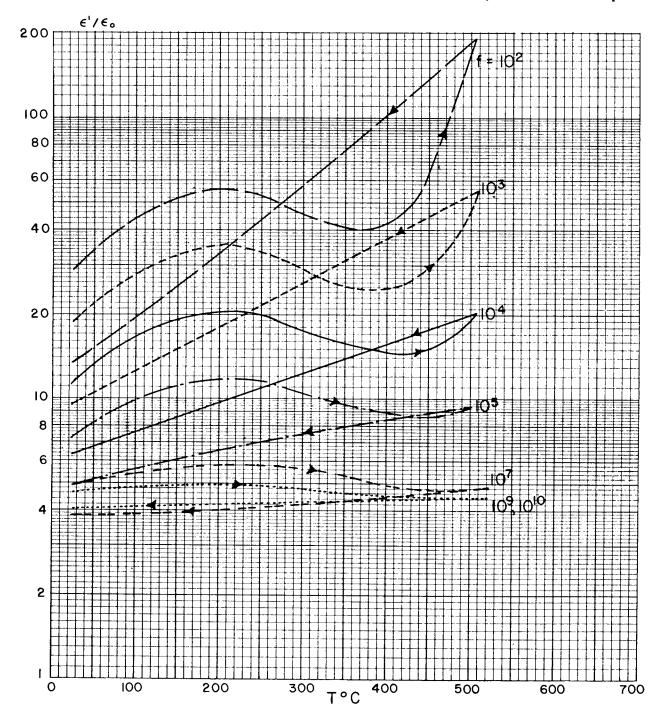
III B 1. Phenolics



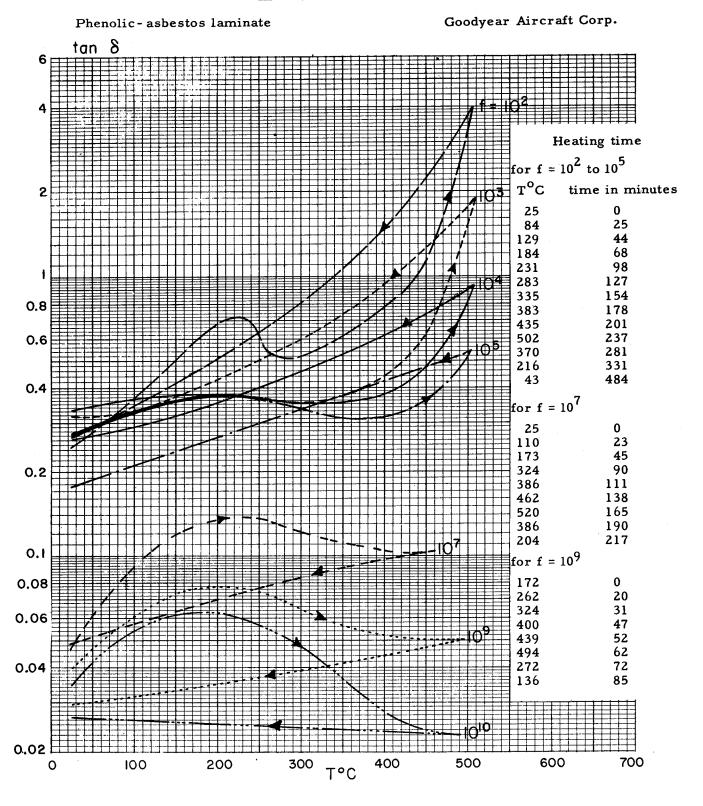
III B 1. Phenolics

Phenolic - asbestos laminate

Goodyear Aircraft Corp.



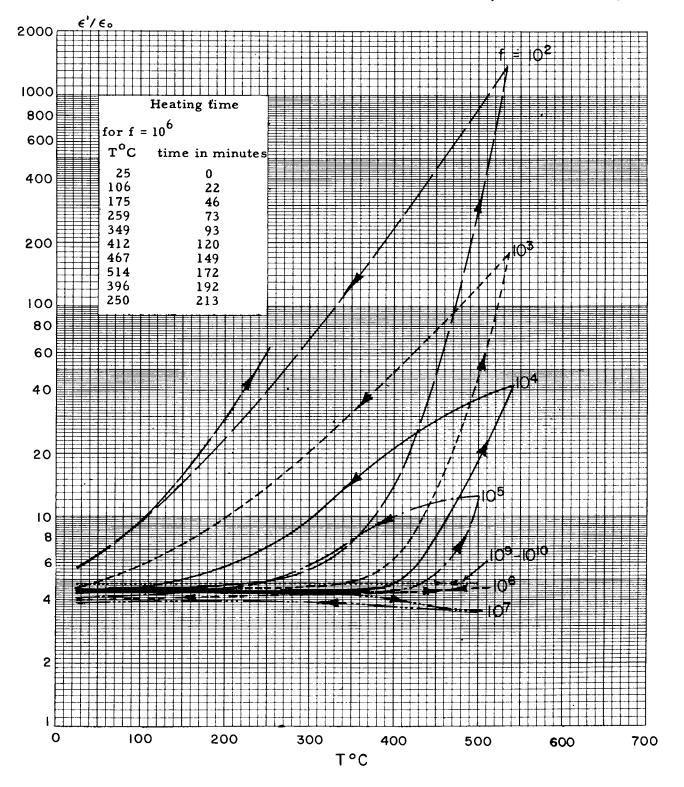
III B 1. Phenolics



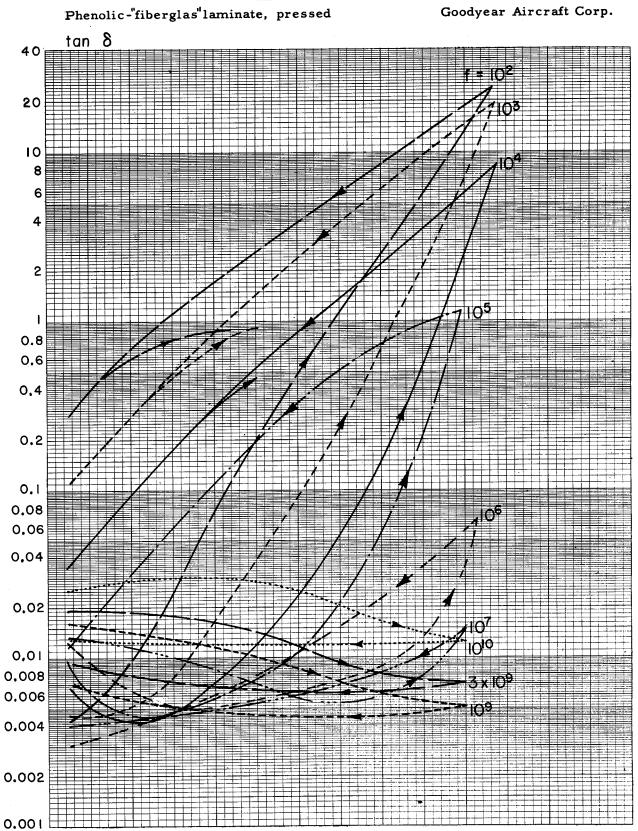
III B 1. Phenolics

 $Phenolic-"fiberglas" laminate, \ pressed$

Goodyear Aircraft Corp.



III B 1. Phenolics

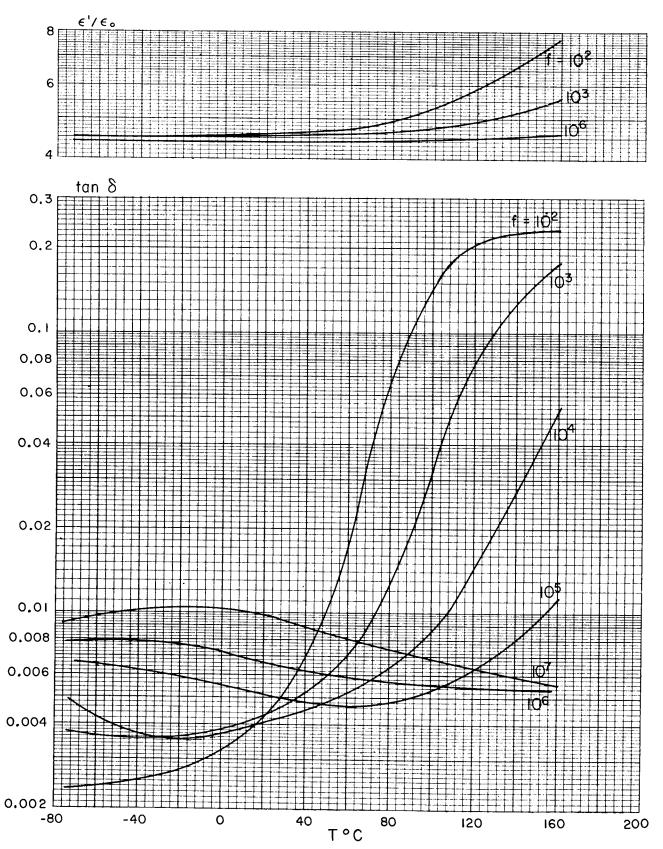


T°C

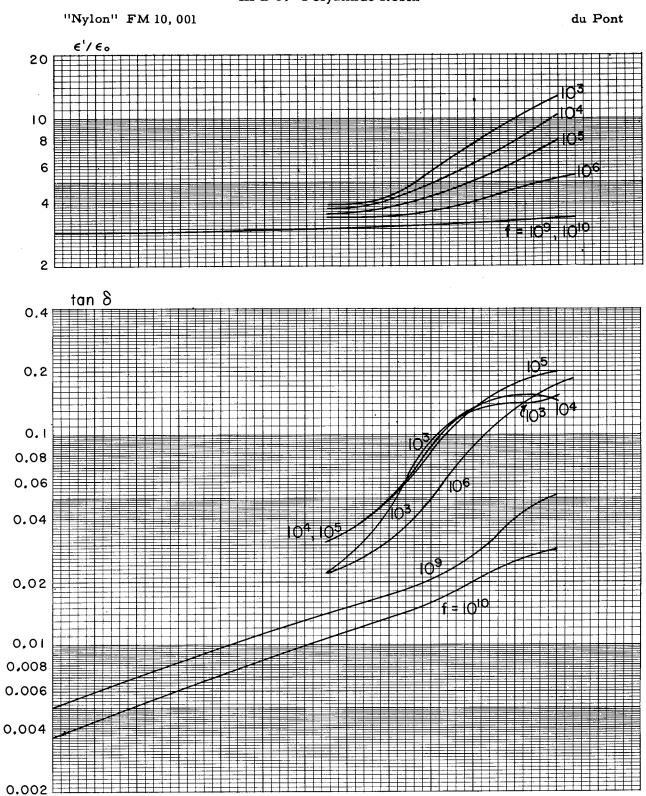
III B 2. Melamine Formaldehyde

"Dilecto" GM-1

Continental Diamond



III B 3. Polyamide Resin



T°C

60

80

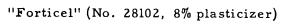
100

-40

-20

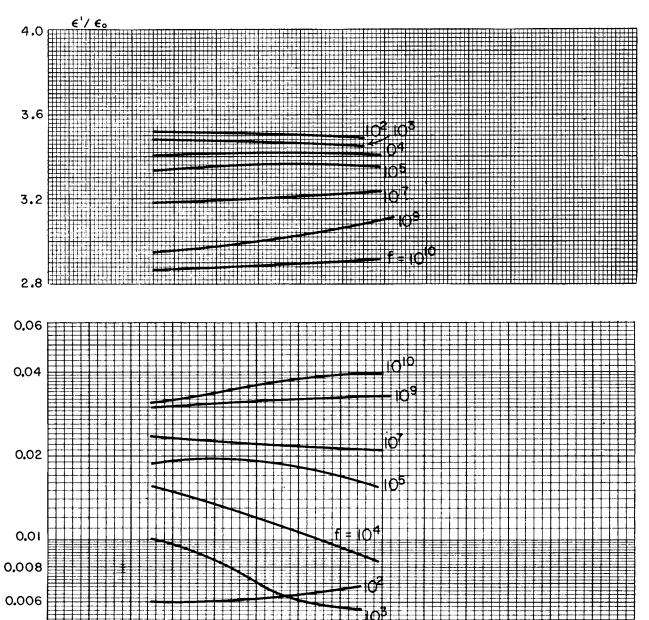
0

III B 4. Cellulose Derivatives



0,004 E

Celanese

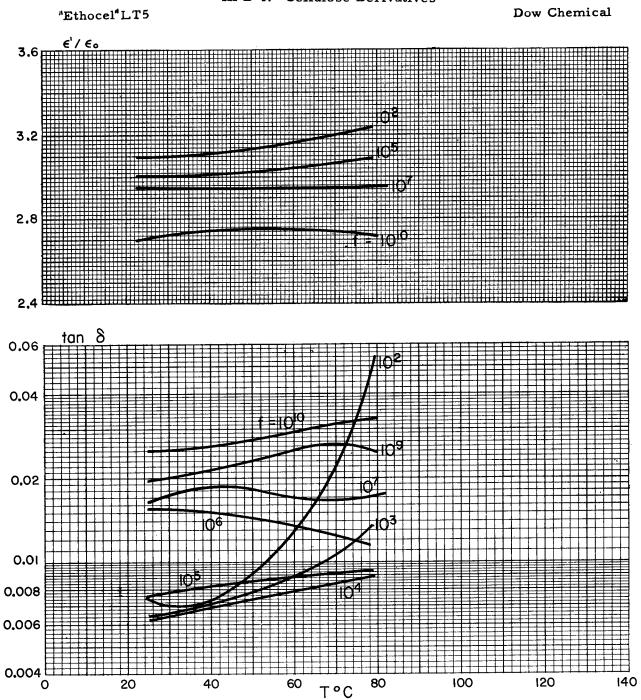


80

100

120

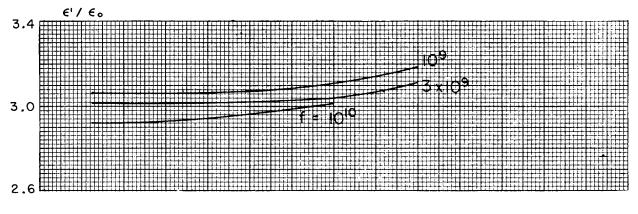
III B 4. Cellulose Derivatives

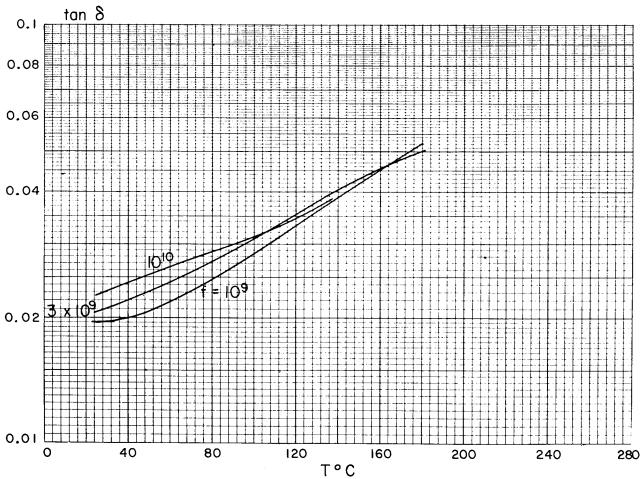


III B 4. Cellulose Derivatives

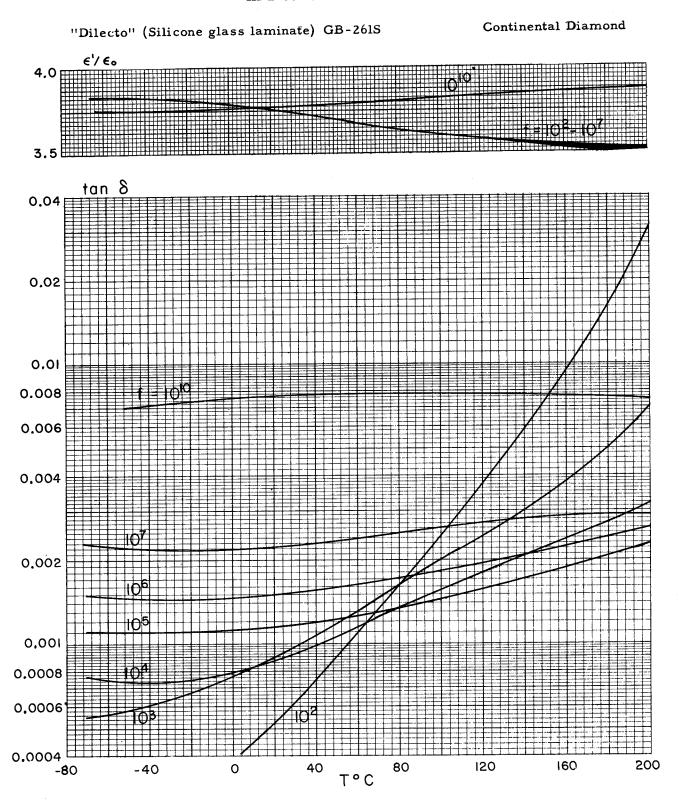
"CTA"

du Pont film dept.

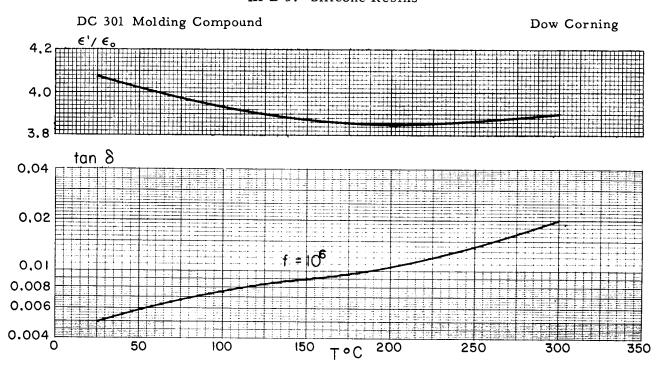


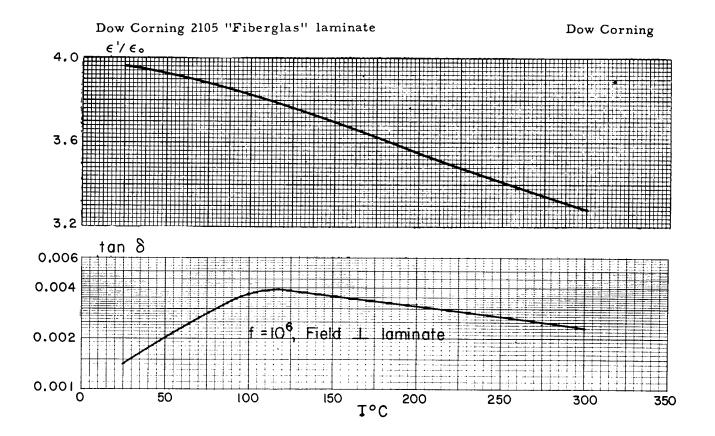


III B 5. Silicone Resins

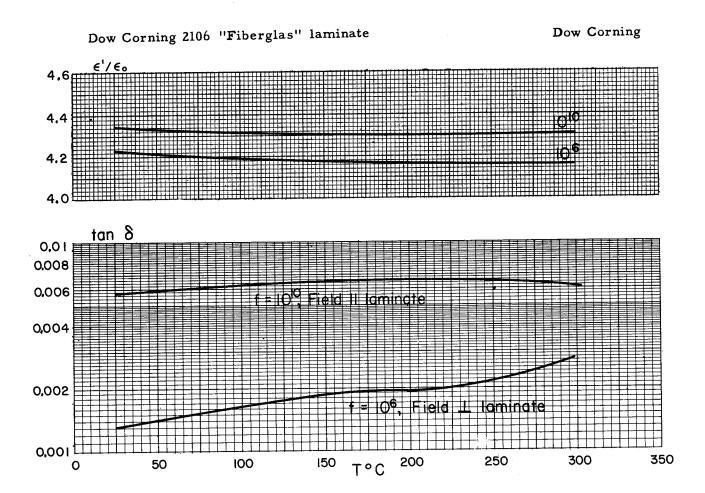


III B 5. Silicone Resins



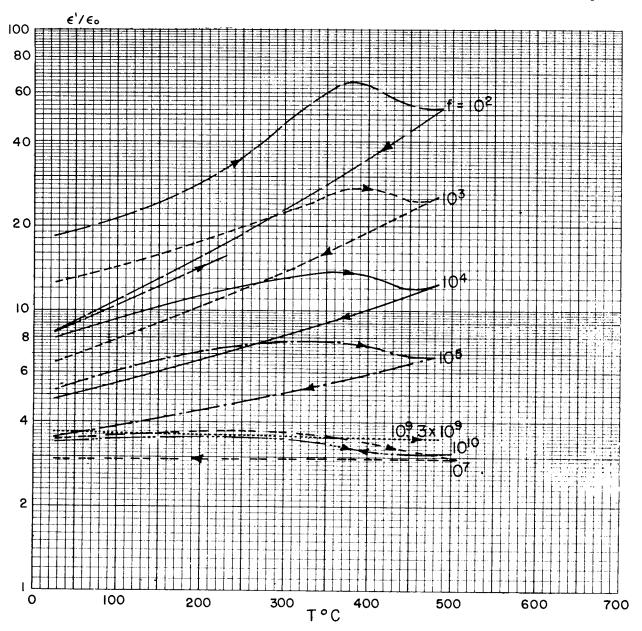


III B 5. Silicone Resins



III B 5. Silicone Resins

Silicone-asbestos laminate



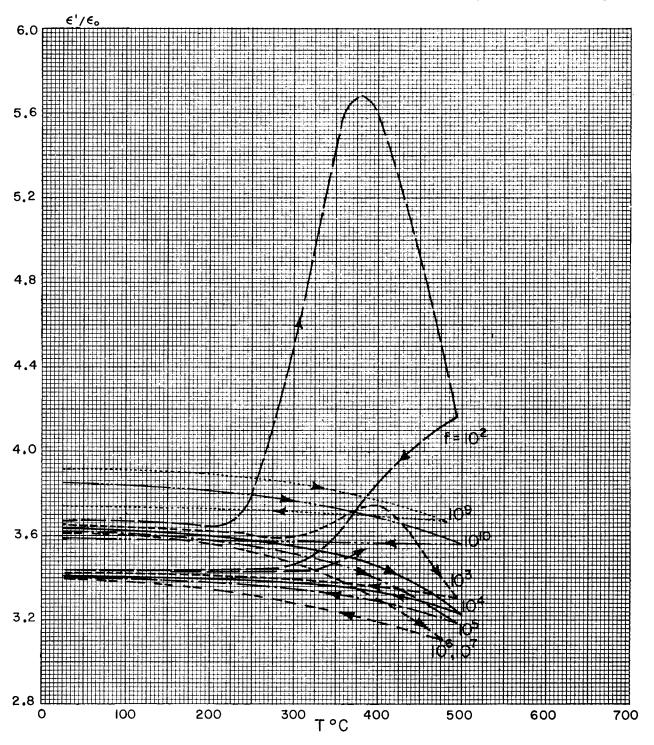
III B 5. Silicone Resins

Goodyear Aircraft Corp. Silicone-asbestos laminate tan 8 Heating time for $f = 10^7$ т^ос time in minutes 25 104 0 25 47 70 87 113 448 167 506 0.8 188 205 388 0.6 0.4 0.08 0.06 0.04 0.02 0.01 400 500 600 700 100 200 300

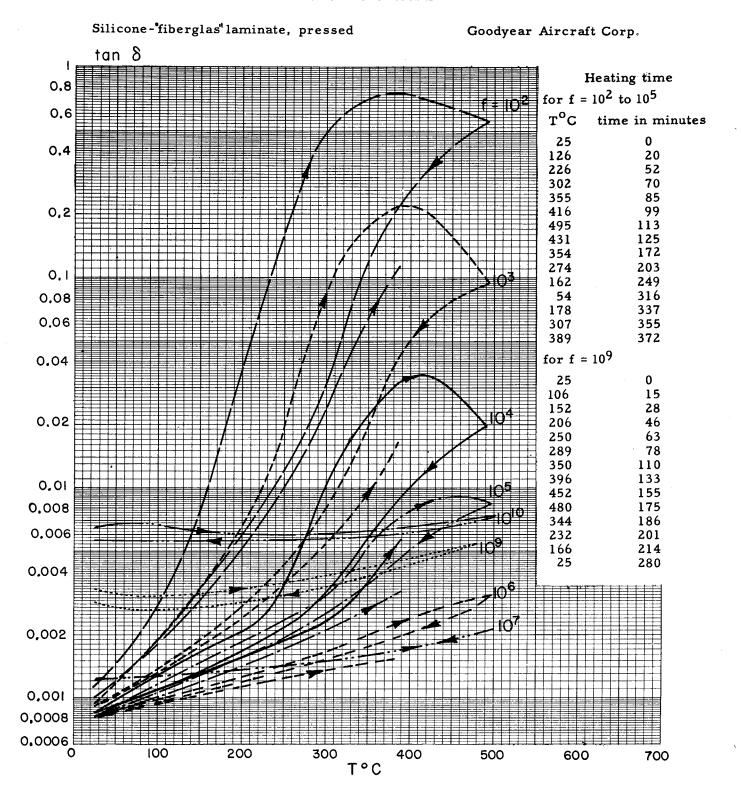
T°C

III B 5. Silicone Resins

Silicone-"fiberglas" laminate, pressed

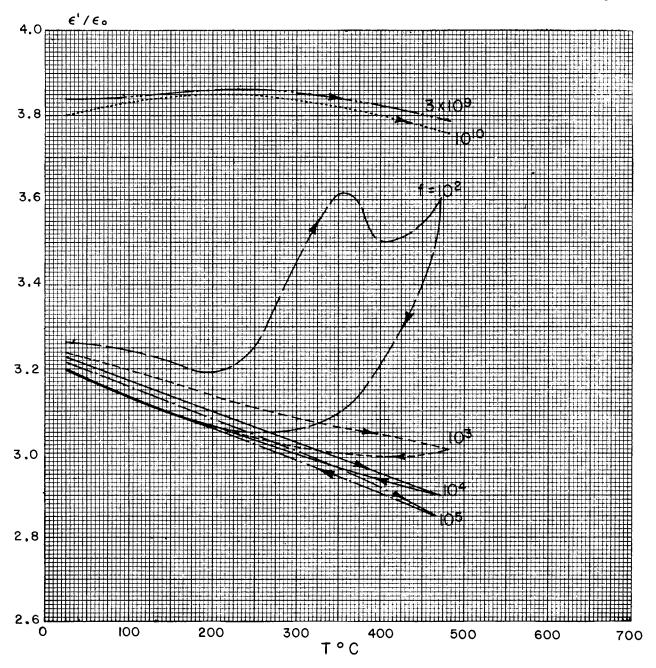


III B 5. Silicone Resins

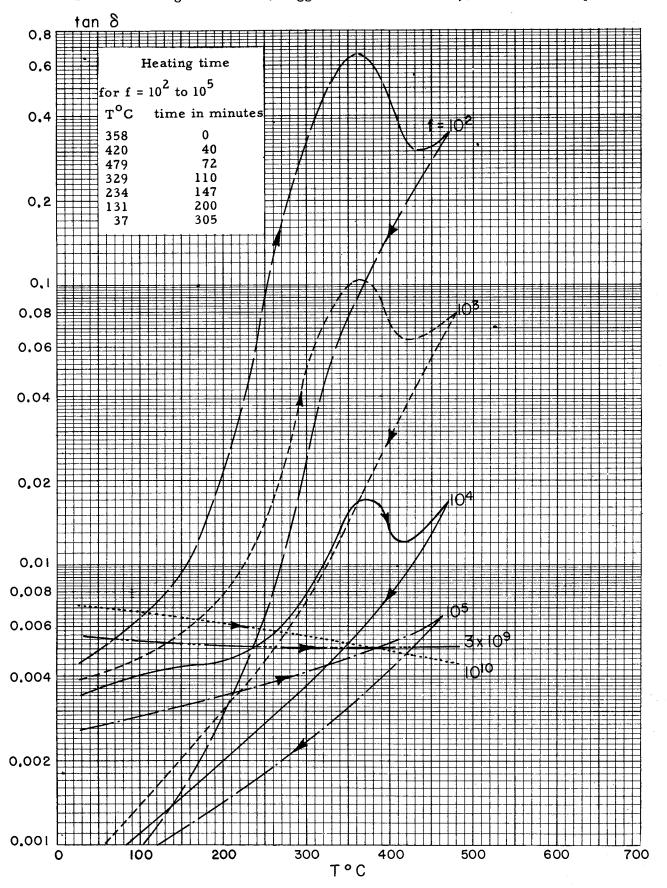


III B 5. Silicone Resins

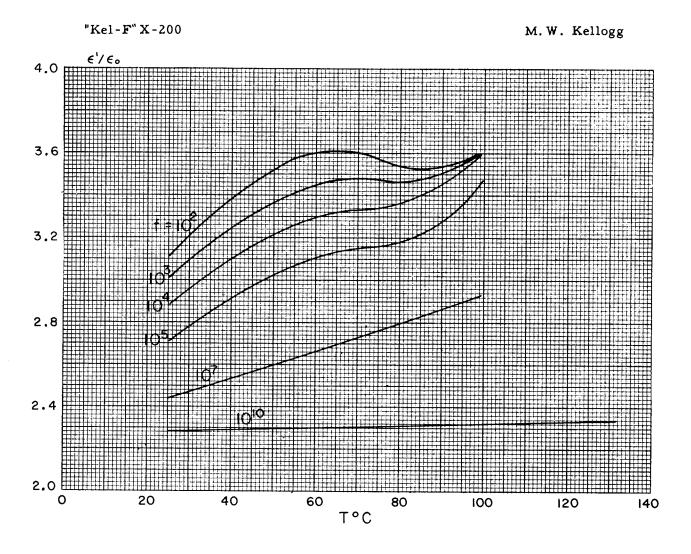
Silicone-"fiberglas" laminate, bagged



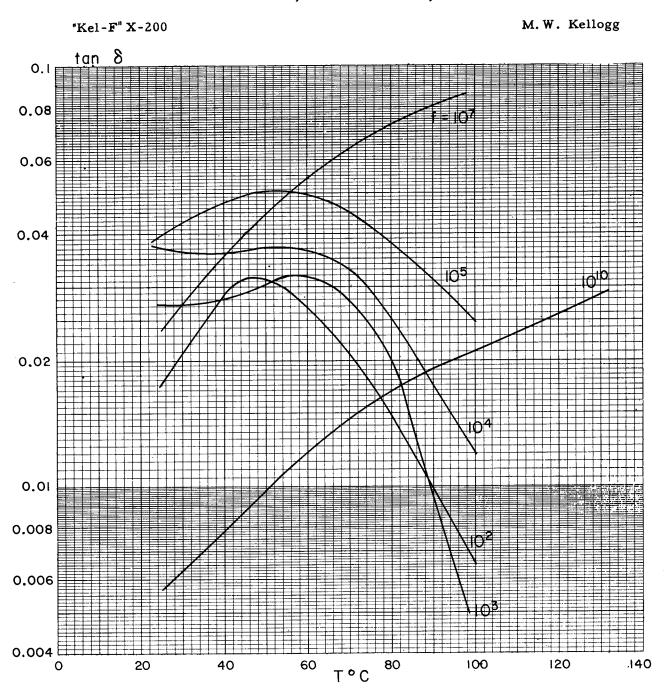
Silicone-"fiberglas" laminate, bagged



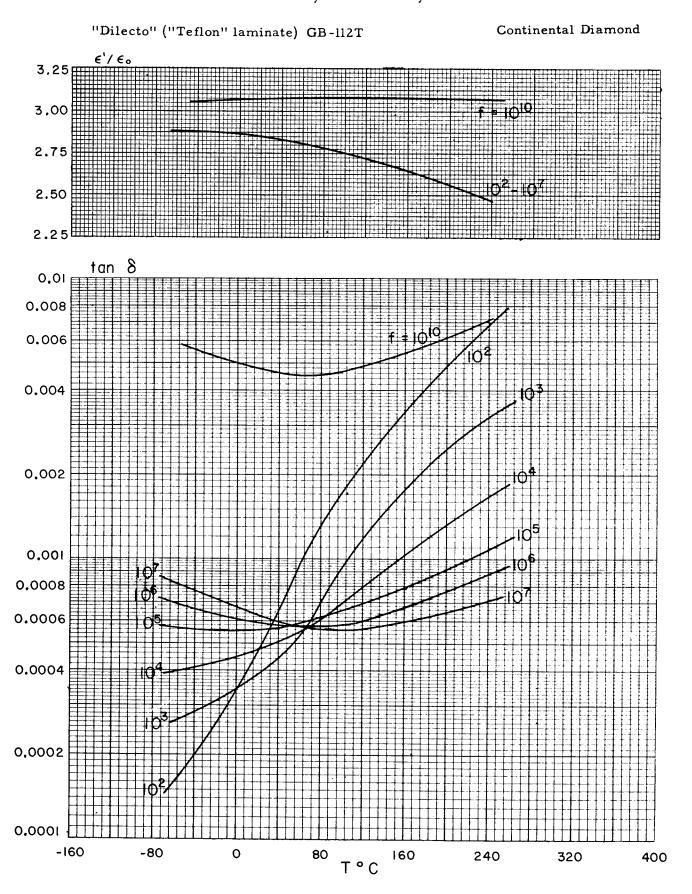
III B 6. Polychlorotrifluoroethylene



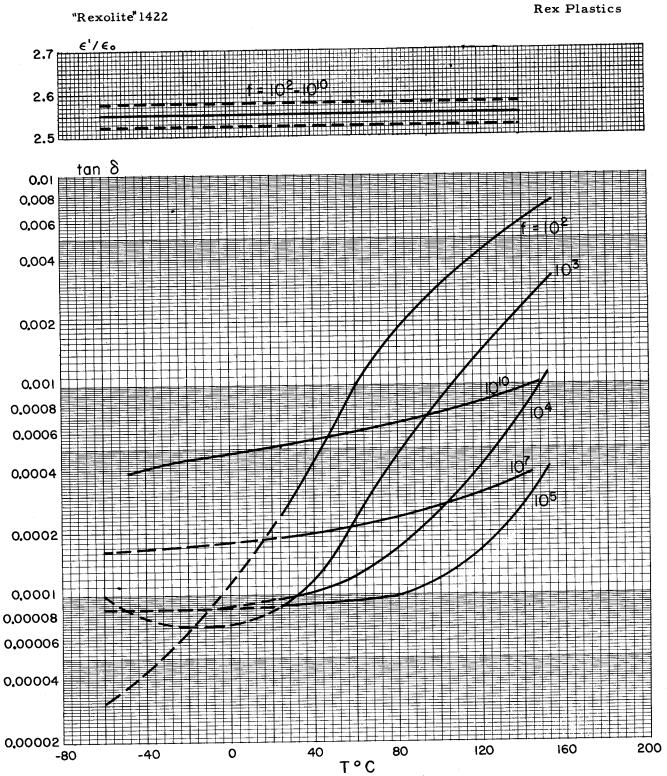
III B 6. Polychlorotrifluoroethylene



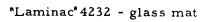
III B 7. Polytetrafluoroethylene



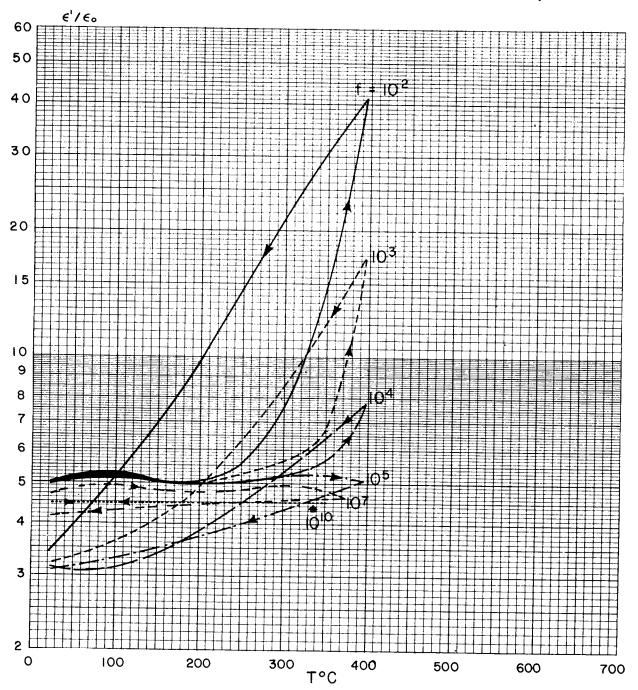
III B 8. Styrene Copolymers



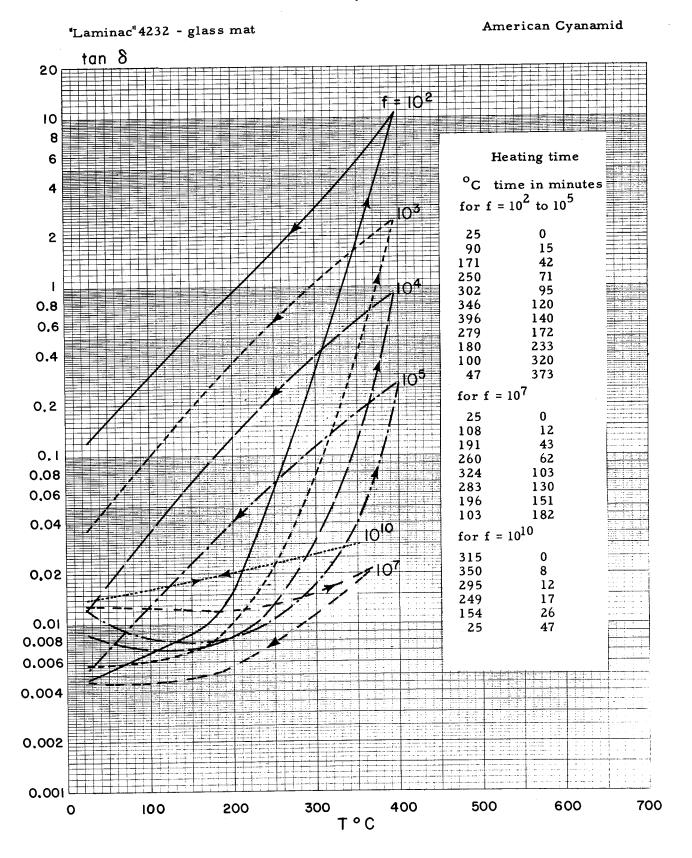
III B 9. Polyesters



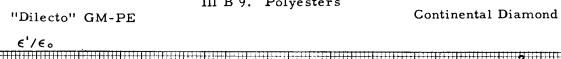
American Cyanamid

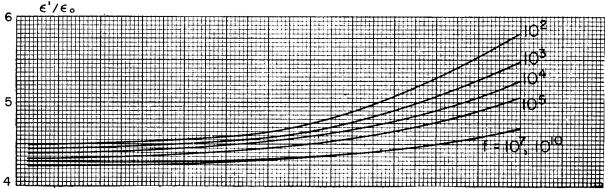


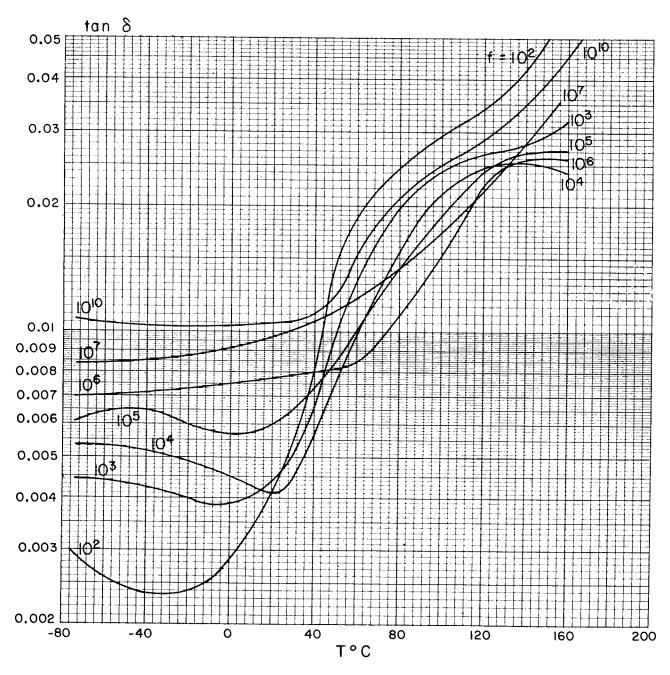
III B 9. Polyesters



III B 9. Polyesters







III B 9. Polyesters

du Pont photo products dept. "Cronar" €'/€。 4.0 ∄ 3.6 3,2 tan 8 0.2 0.1 0.08 0.06 0.04 0,02 0.01 0.008

160

120

T°C

80

200

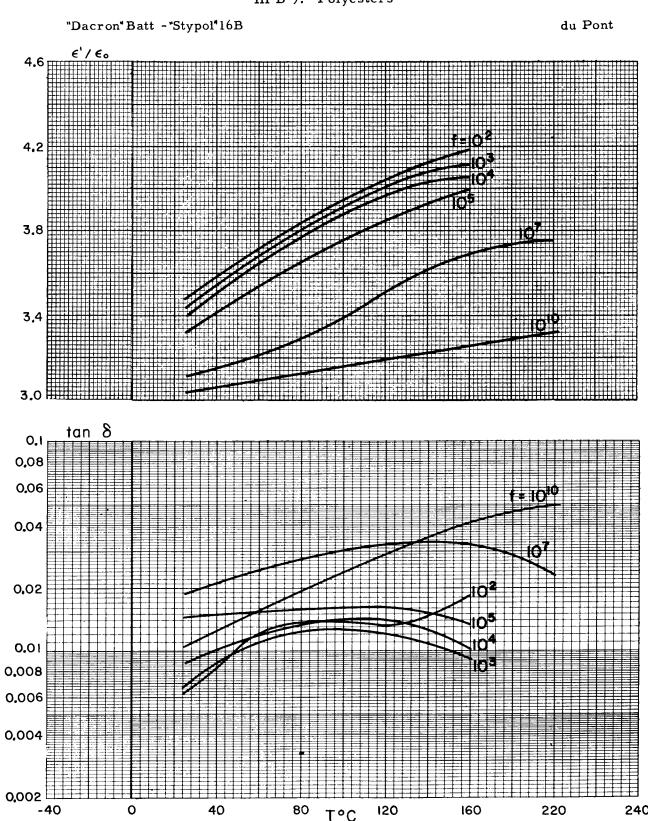
280

240

0.006

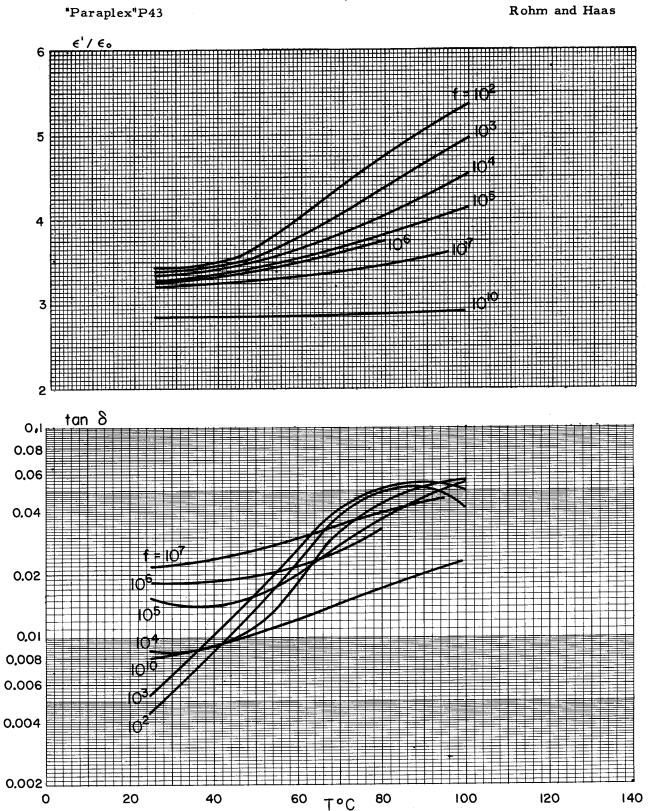
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III B 9. Polyesters

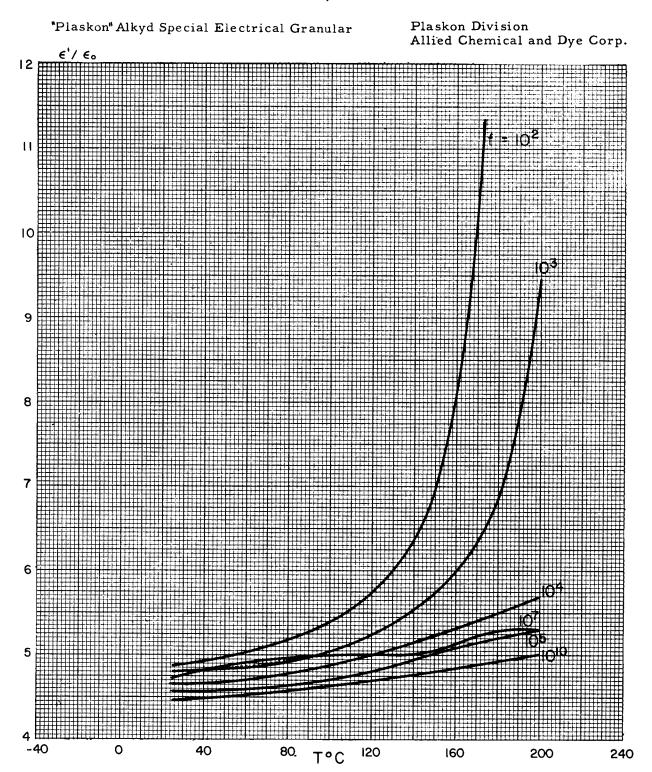


T°C

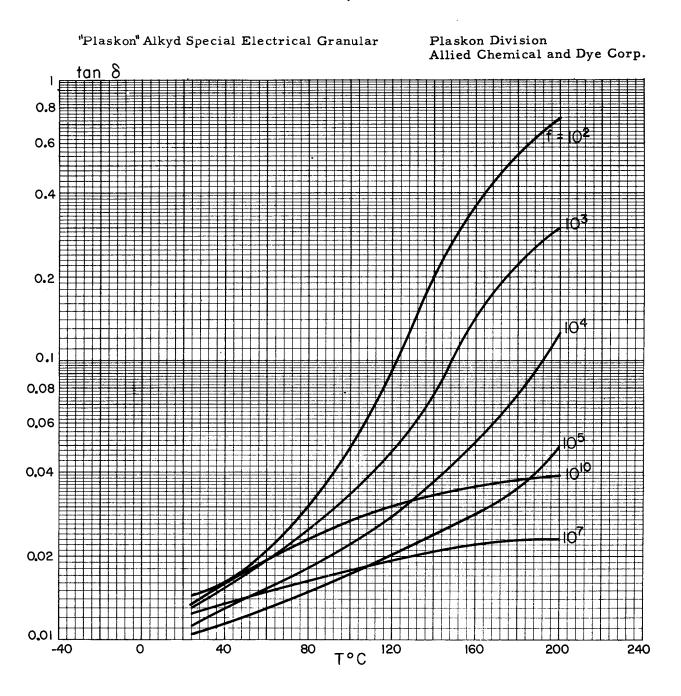
III B 9. Polyesters



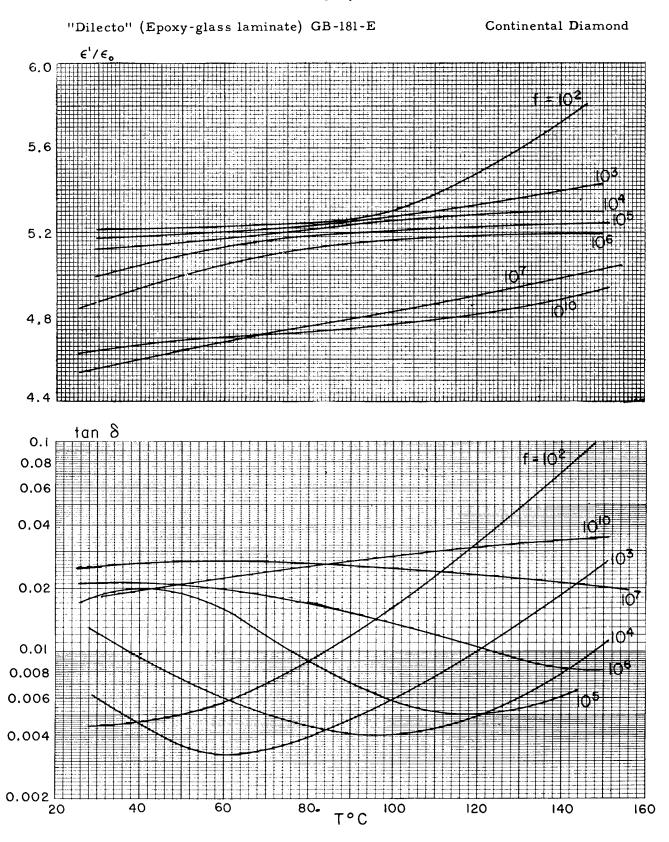
III B 10. Alkyd Resins



III B 10. Alkyd Resins



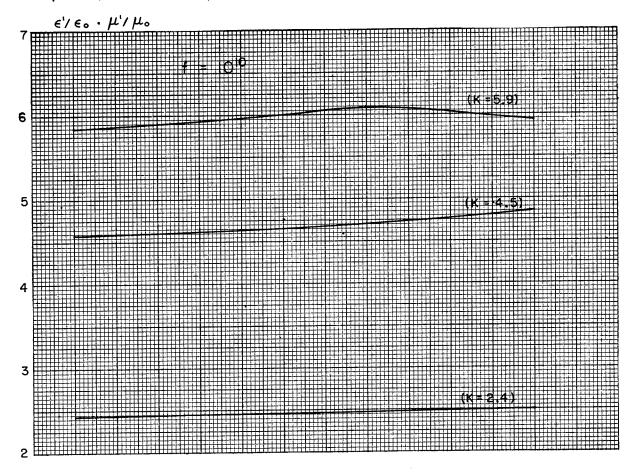
III B 11. Epoxy Resins

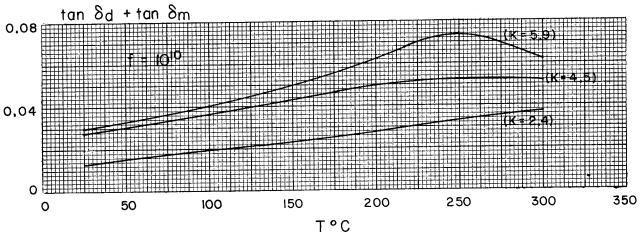


III B 11. Epoxy Resins

"Eccofoam" HiK (500°F) (K=5.9, K=4.5, K=2.4)

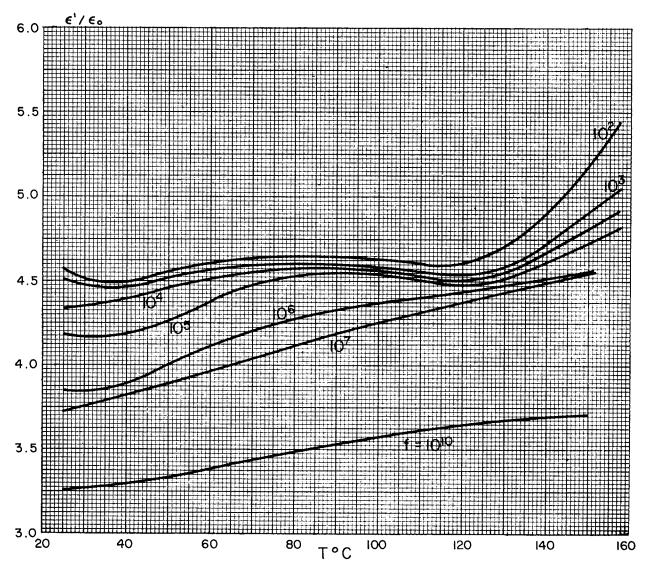
Emerson and Cuming



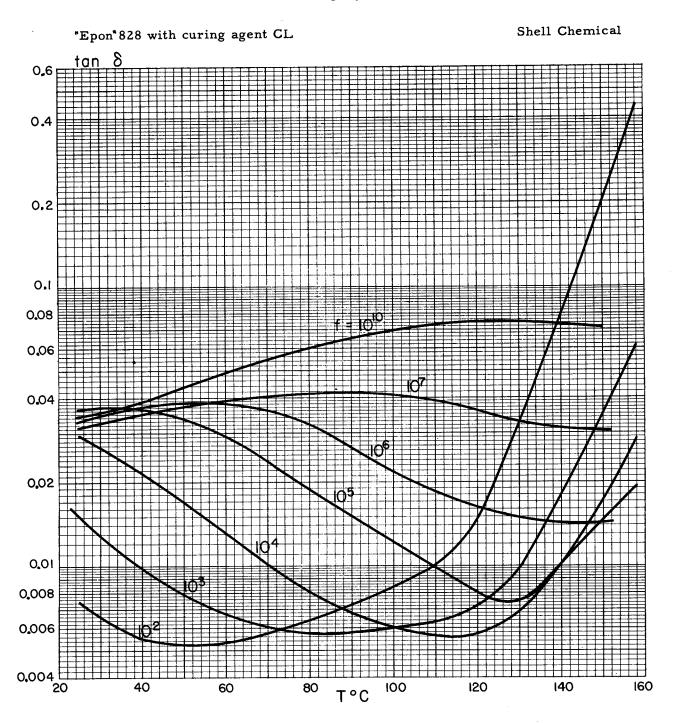


III B 11. Epoxy Resins

"Epon" 828 with curing agent CL

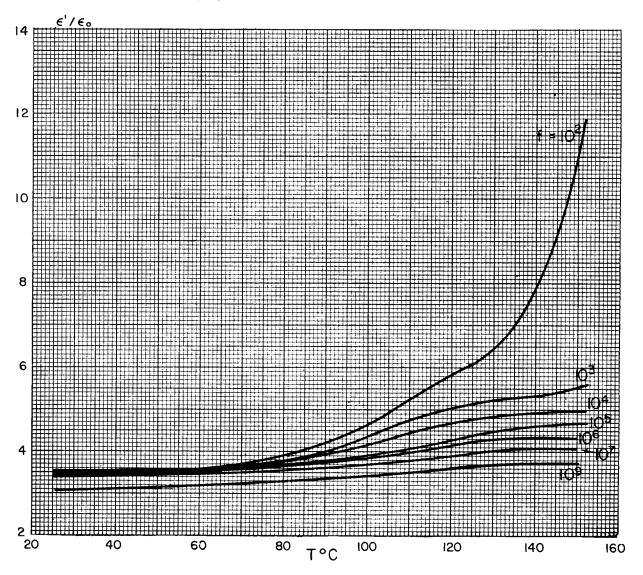


III B 11. Epoxy Resins

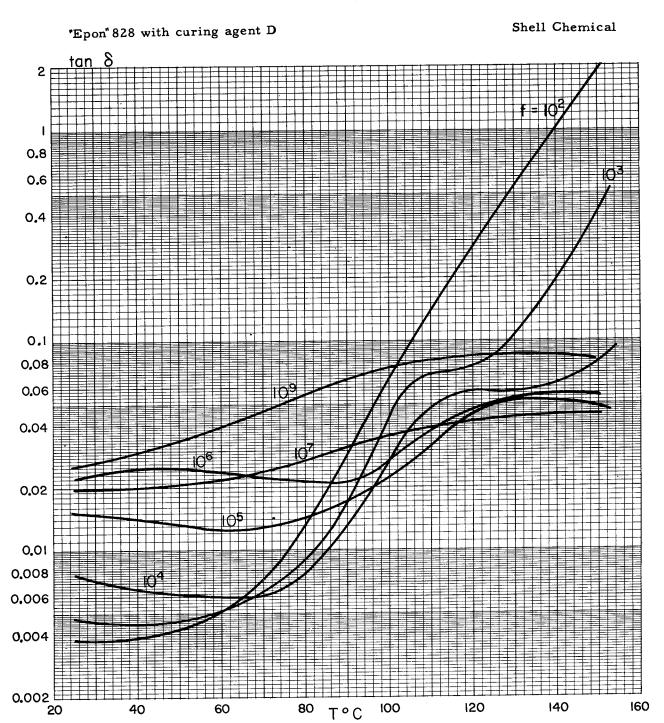


III B 11. Epoxy Resins

"Epon" 828 with curing agent D

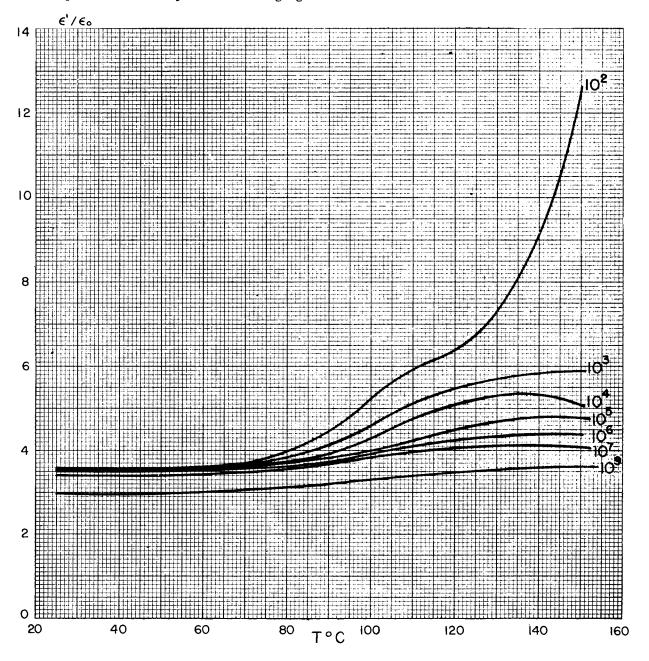


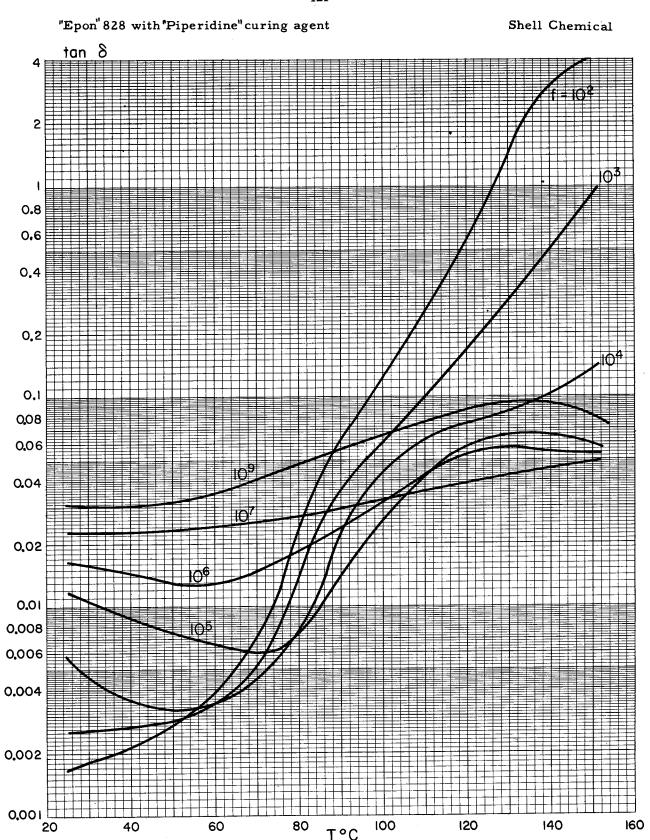
III B 11. Epoxy Resins



III B 11. Epoxy Resins

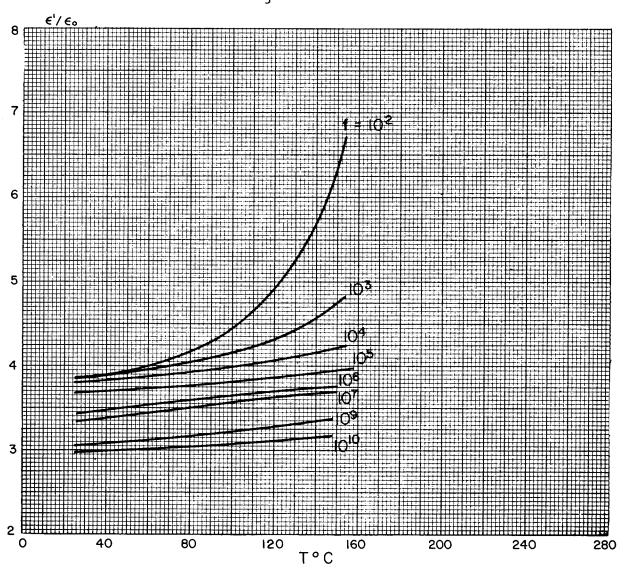
"Epon" 828 with "Piperidine" curing agent



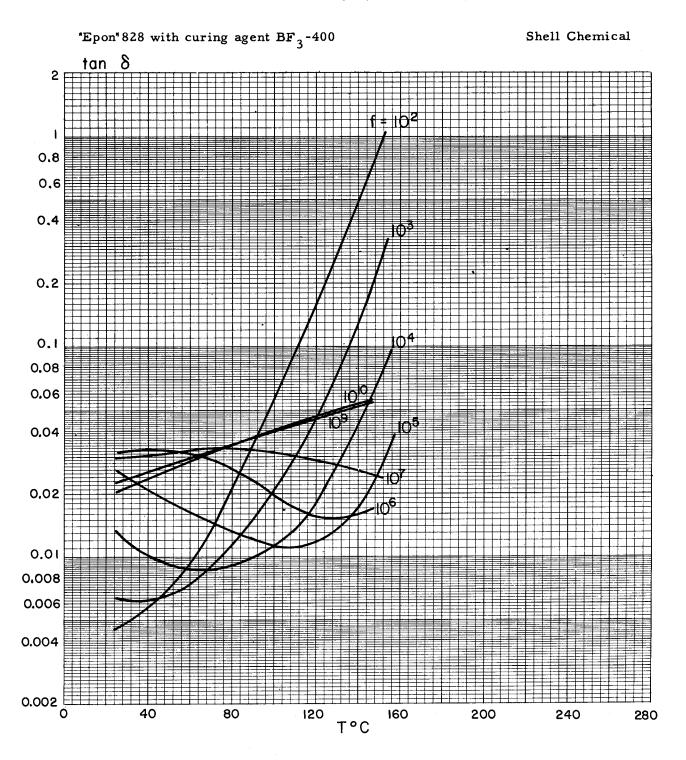


III B 11. Epoxy Resins

"Epon" 828 with curing agent BF_3 -400

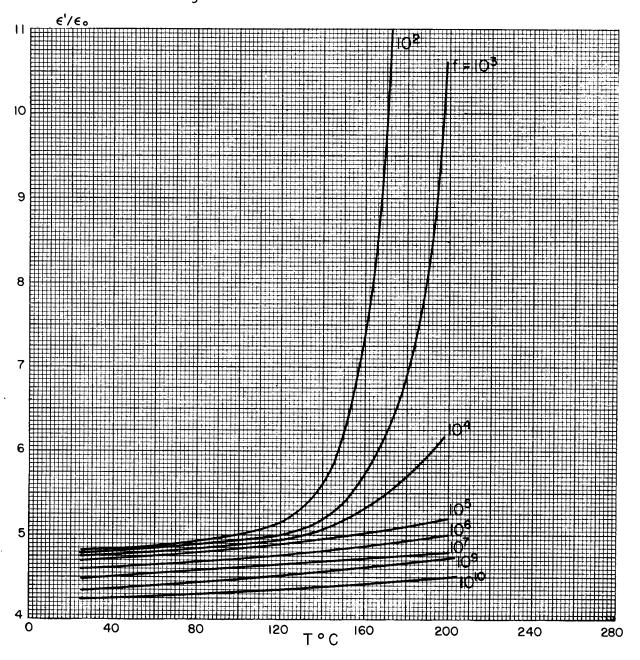


III B 11. Epoxy Resins

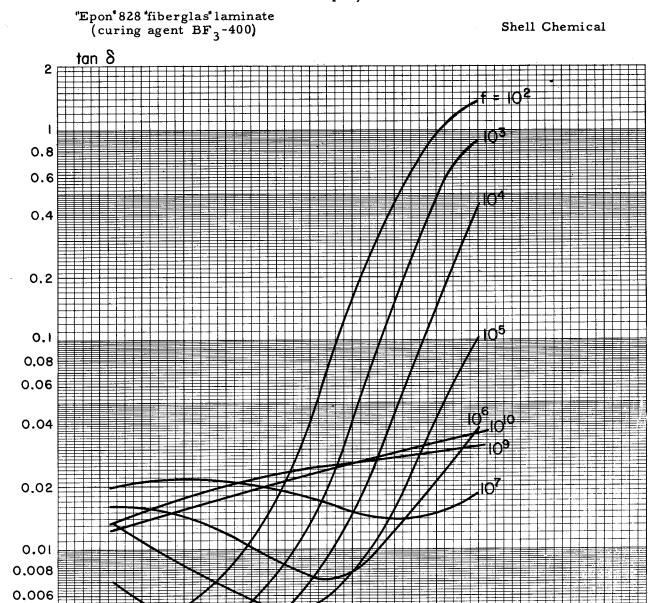


III B 11. Epoxy Resins

"Epon" 828 fiberglas laminate (curing agent BF₃-400)



III B 11. Epoxy Resins



T°C

80

160

240

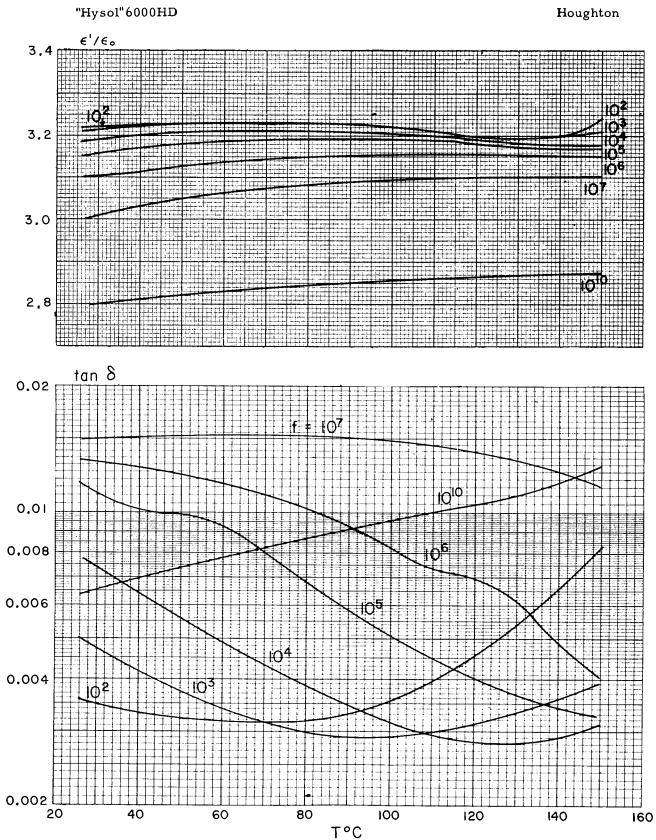
280

200

0,004

0.002

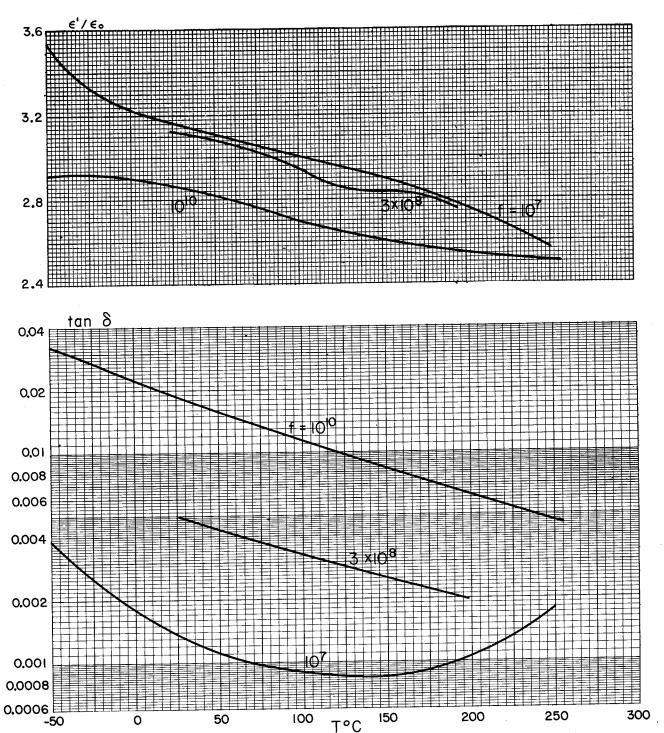
III B 11. Epoxy Resins



III C. Elastomers

Silicone Rubber SE 450

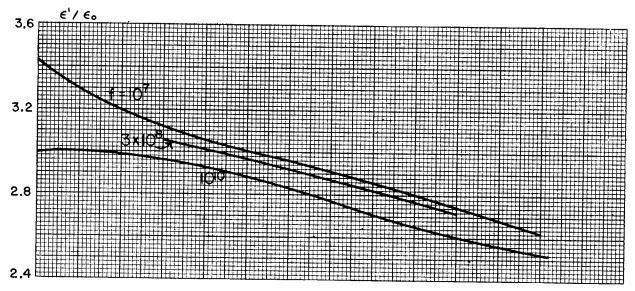
General Electric, Waterford, N.Y.

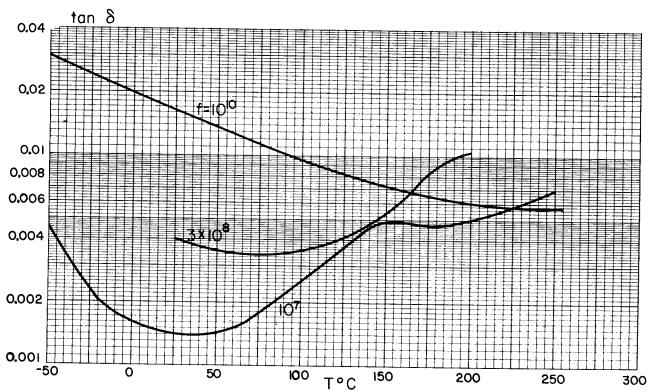


III C. Elastomers

Silicone Rubber SE 460

General Electric, Waterford, N.Y.

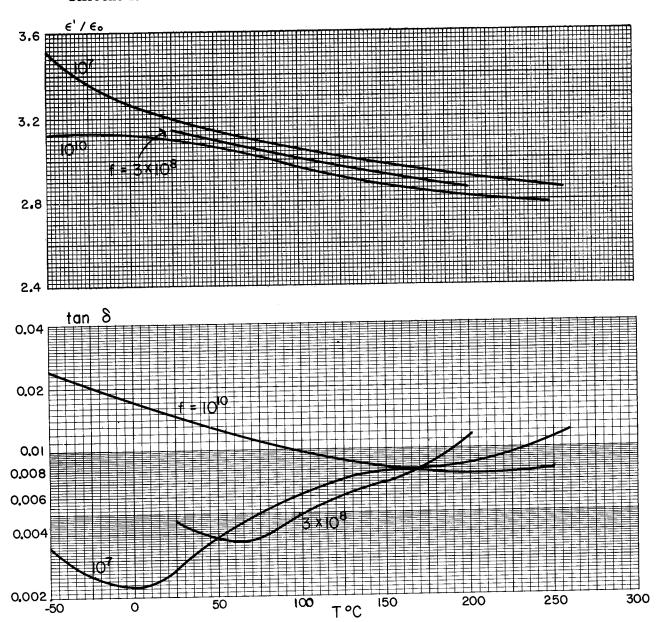




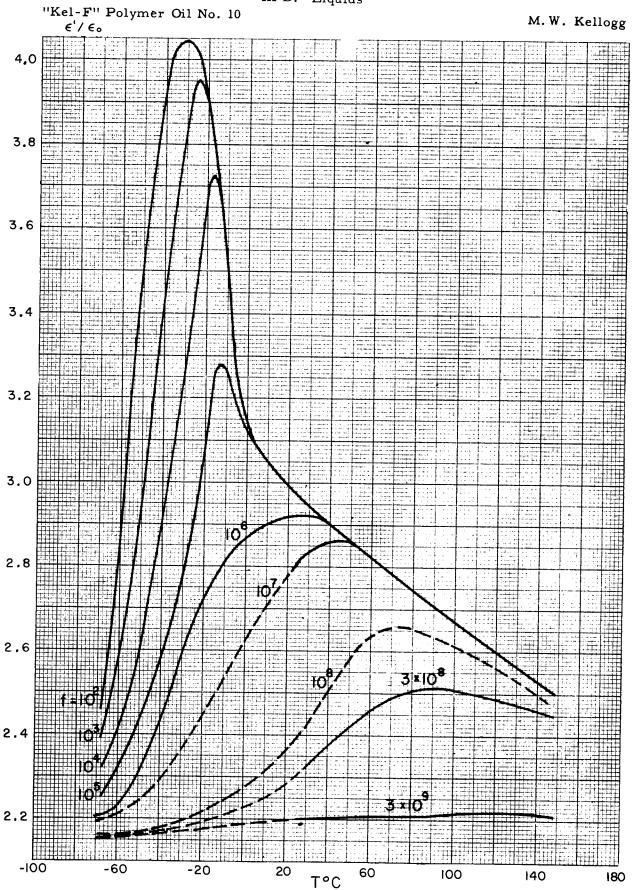
III C. Elastomers

Silicone Rubber SE 972

General Electric, Waterford, N.Y.



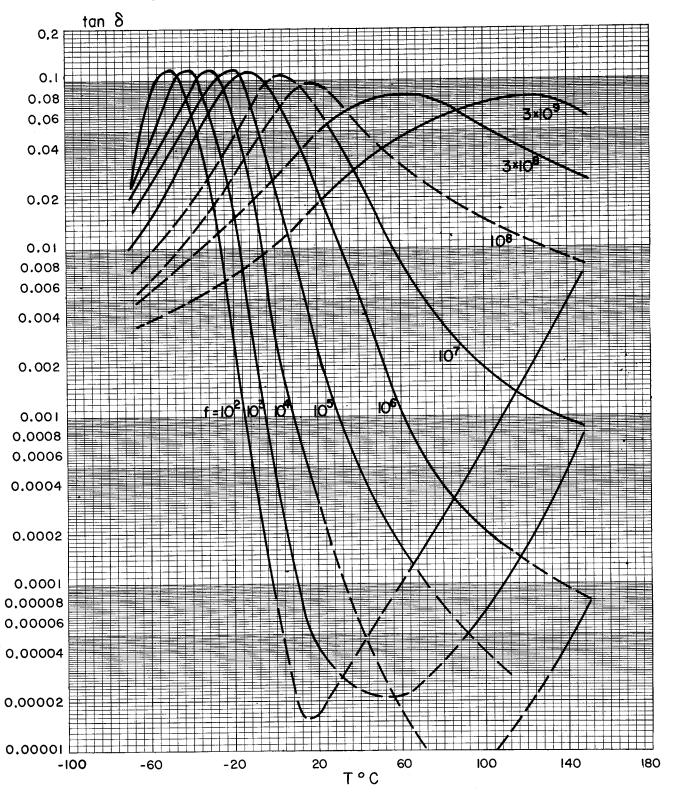
III D. Liquids



III D. Liquids

"Kel-F" Polymer Oil No. 10

M.W. Kellogg



IV. Ferromagnetic Dielectrics

Complete evaluation of a magnetic material for both scientific study and engineering design requires measurement of ** and ** vs. frequency, temperature, a-c field strength, and d-c bias. Phenomena of interest range from the very slow changes in magnetization with time at low temperatures to the instantaneous permeability at high microwave power.

In this section we have limited our data to κ^* and κ^* vs. frequency at low a-c field strengths and fixed temperatures and to the quasi-static hysteresis loops at room temperature. At frequencies up to 10 Mc we have also plotted $\kappa_m^{\prime\prime}/\kappa_m^\prime$, a figure of merit for core materials. In the literature this is designated as $1/\mu'Q$ and called loss factor.

For many of the laboratory materials and some of the commercial materials other measurements have been made such as:

D-c conductivity vs. temperature,

- $\kappa \text{**}, \ \kappa \text{**}_{m} \text{ vs. temperature at fixed frequencies, low fields,}$
- **, ** vs. field strength at fixed frequencies and temperatures.

 Some of this information is included in Tech. Rep. 97, a revised version of which will be published in Revs. Mod. Phys., July, 1957, and in a forthcoming technical report by D.J. Epstein. Other data are available from the measurements group file.

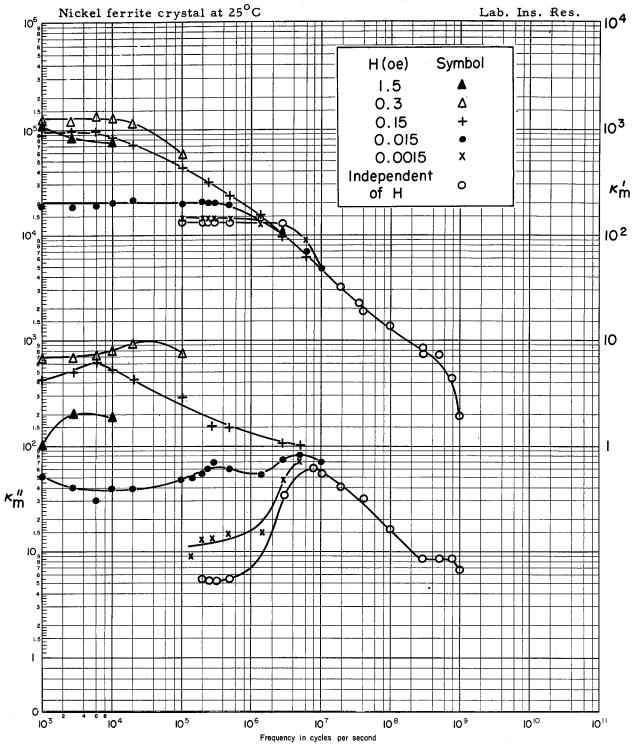
Details of the preparation of ferrites have been given in Tech. Rep. 78 by G. Economos.

Unless otherwise noted, measurements were taken at $26^{\circ}C \pm 1$. σ is given in mho/m.

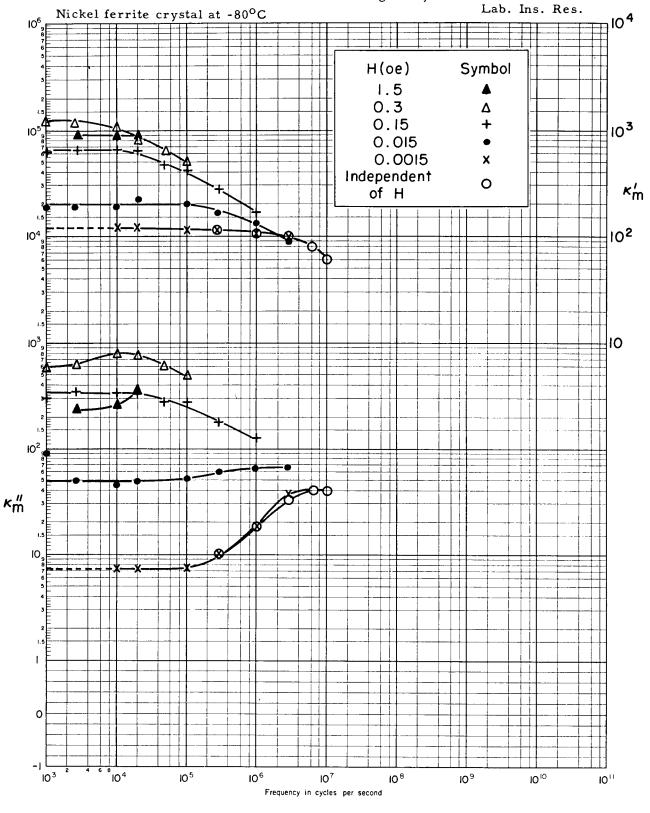
Low-frequency dielectric measurements marked were four-terminal measurements made to eliminate electrode effects.

IV A. Low Field-Strength Data at Fixed Temperatures as a Function of Frequency

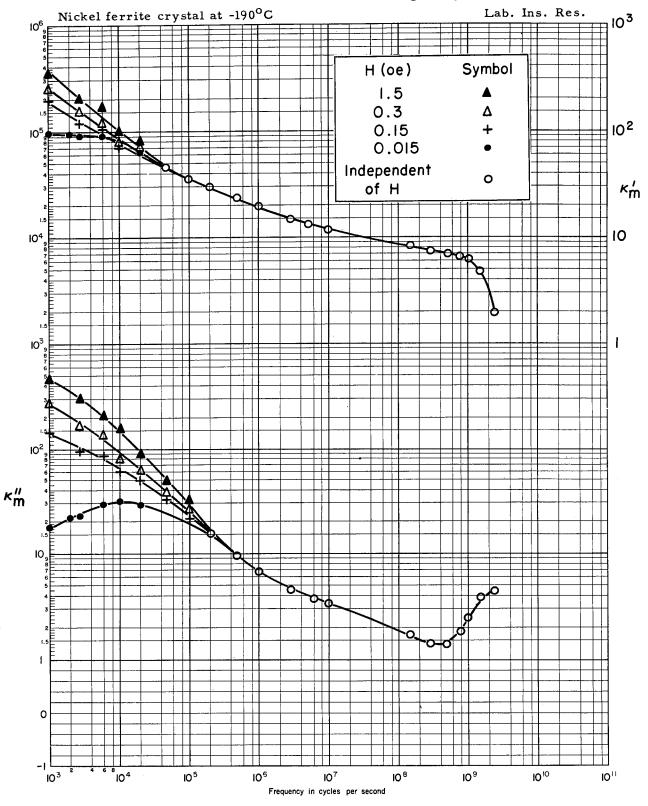
1. Nickel Ferrite, Single Crystal

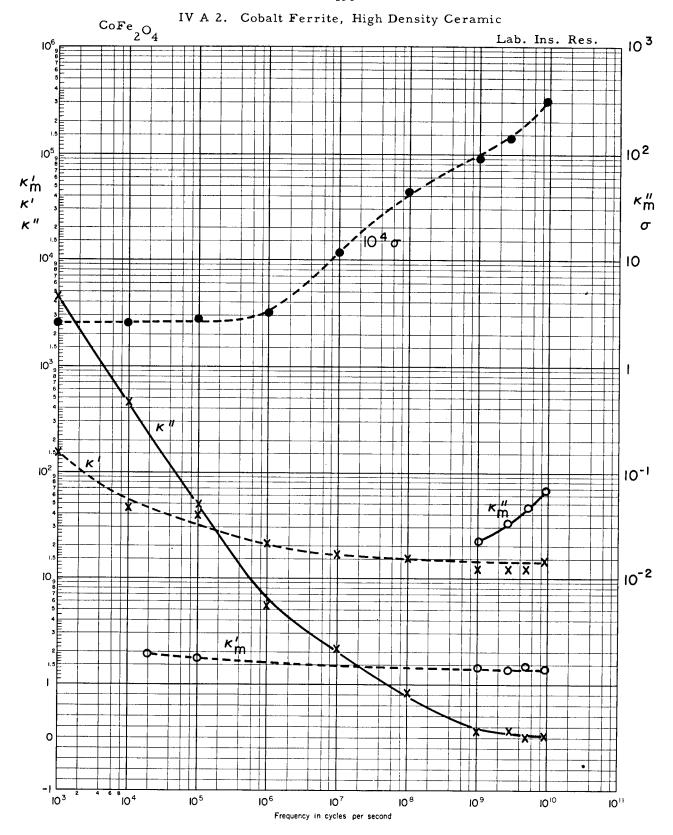


IV A 1. Nickel Ferrite, Single Crystal

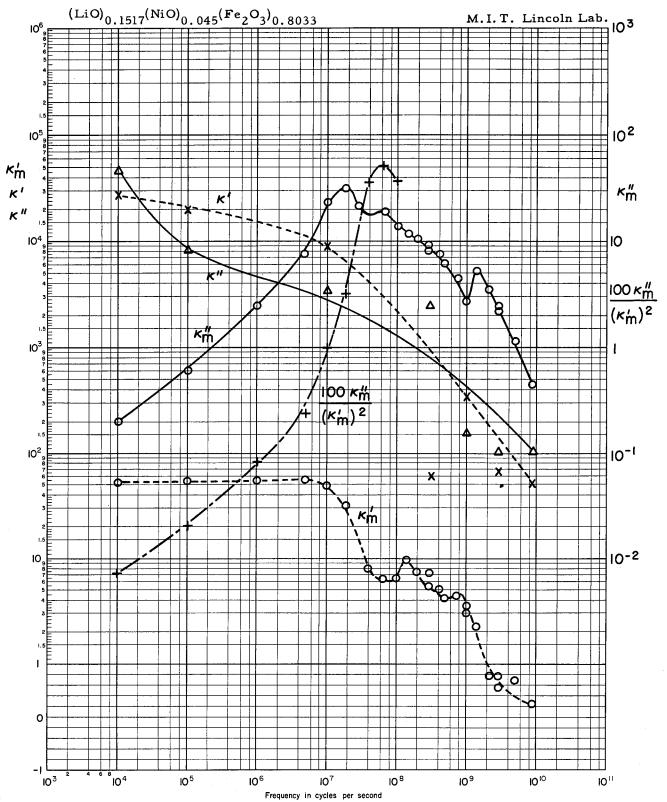


IV A 1. Nickel Ferrite, Single Crystal

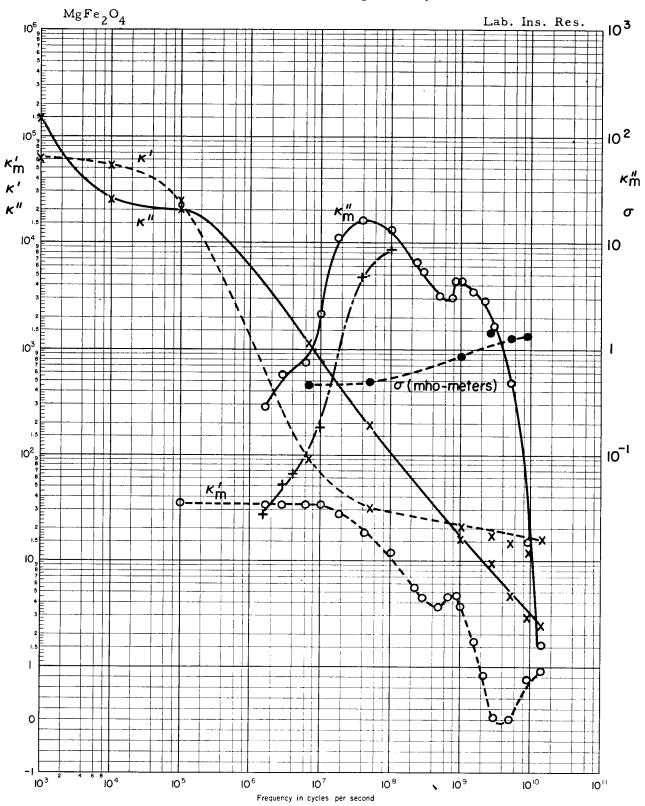




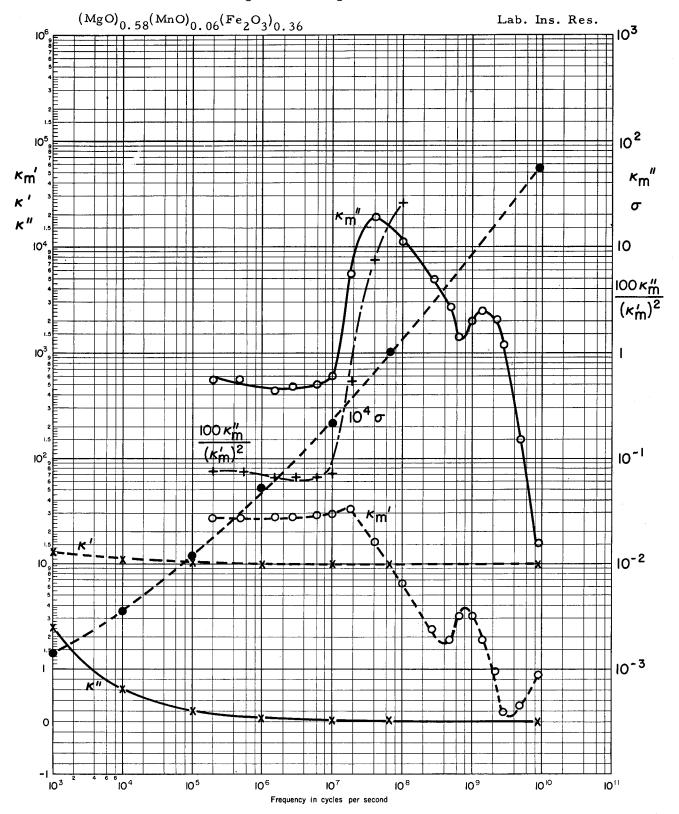
IV A 3. Lithium-Nickel Ferrite Ceramic



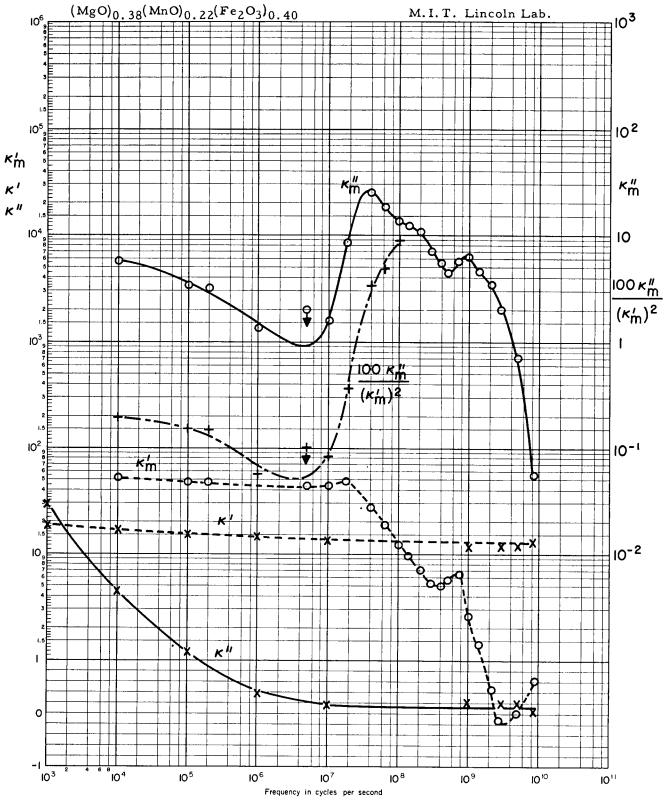
IV A 4. Magnesium Ferrite, High Density Ceramic



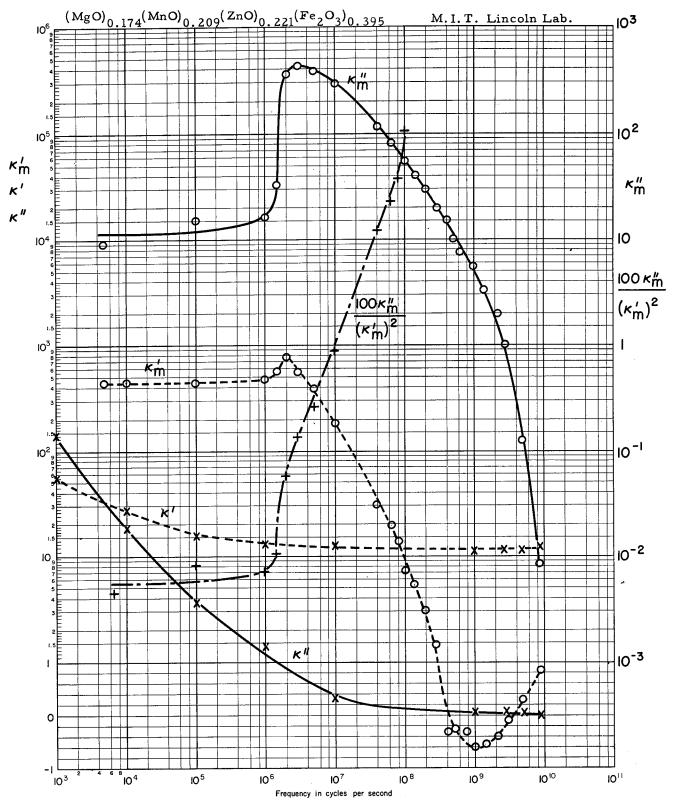
IV A 5. Magnesium Manganese Ferrite Ceramics



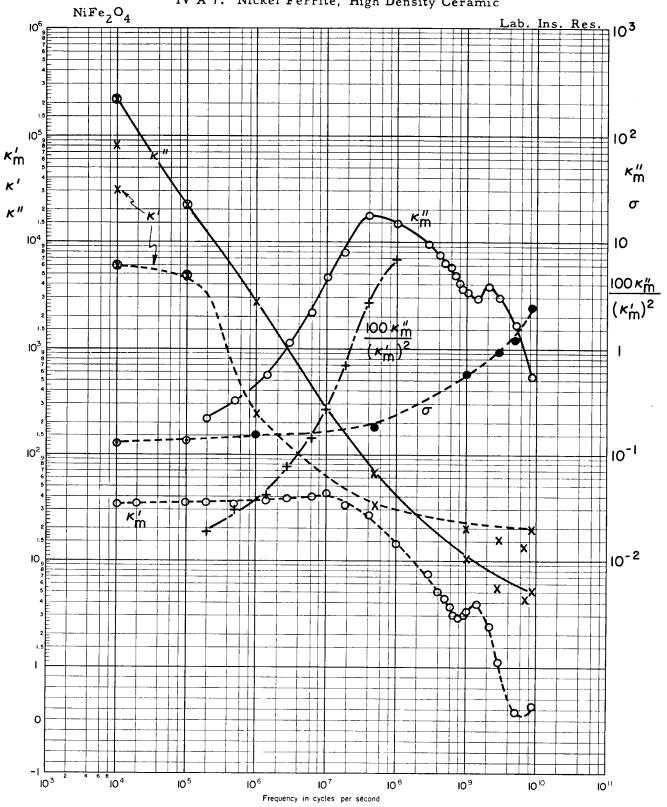
IV A 5. Magnesium-Manganese Ferrite Ceramics



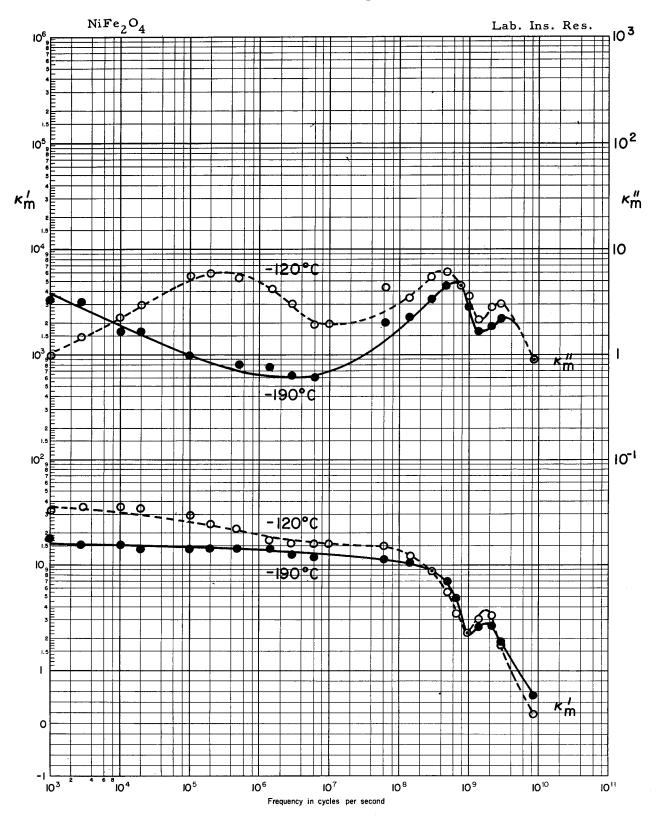
IV A 6. Magnesium-Manganese-Zinc Ferrite Ceramic



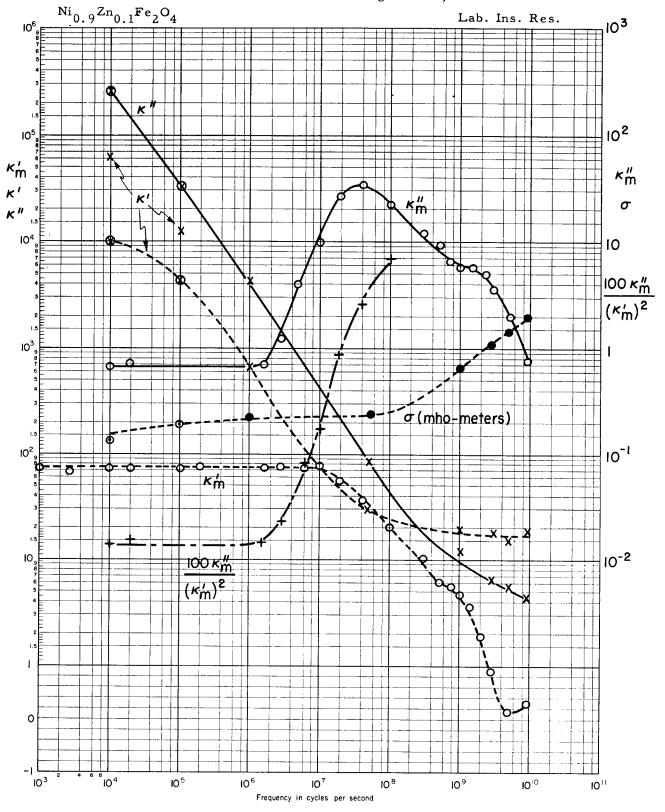
IV A 7. Nickel Ferrite, High Density Ceramic



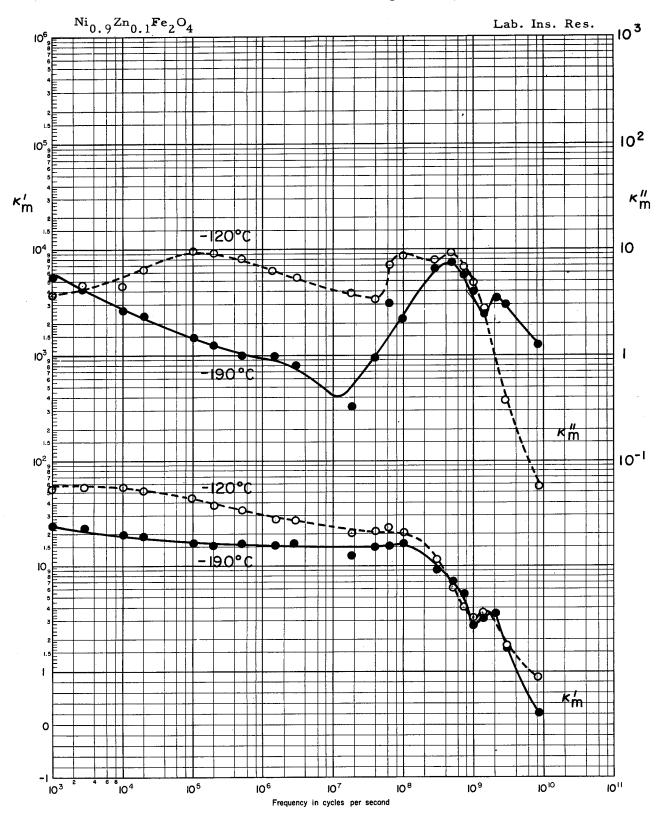
IV A 7. Nickel Ferrite, High Density Ceramic

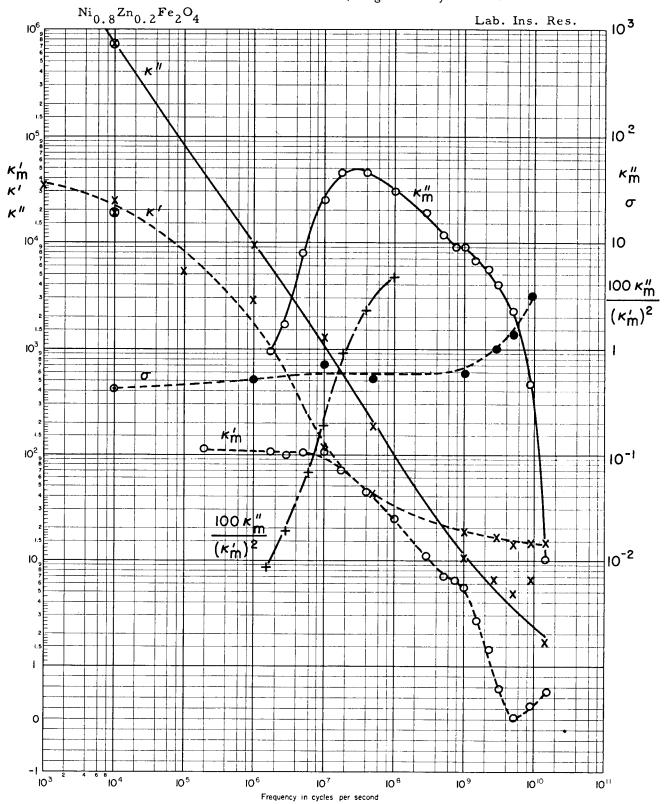


IV A 8. Nickel-Zinc Ferrites, High Density Ceramics

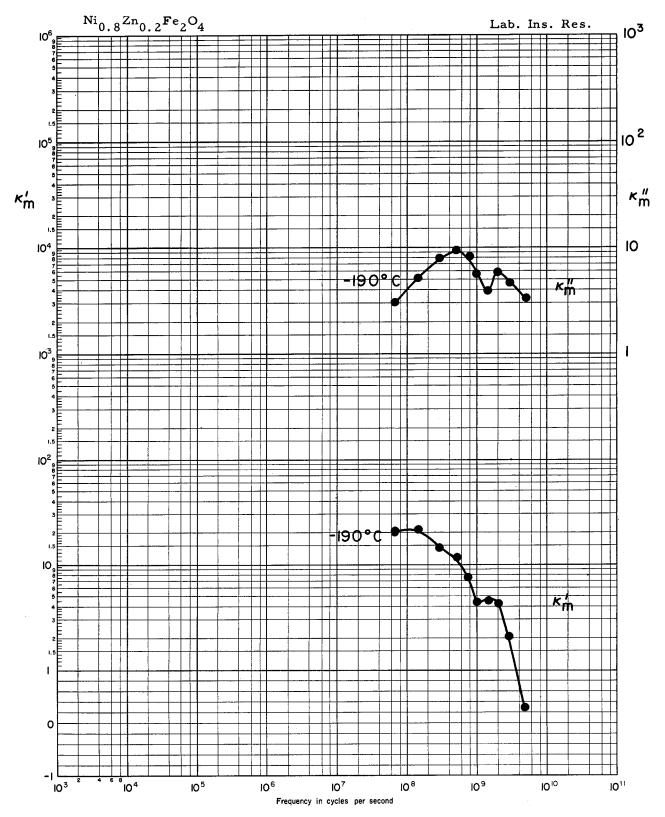


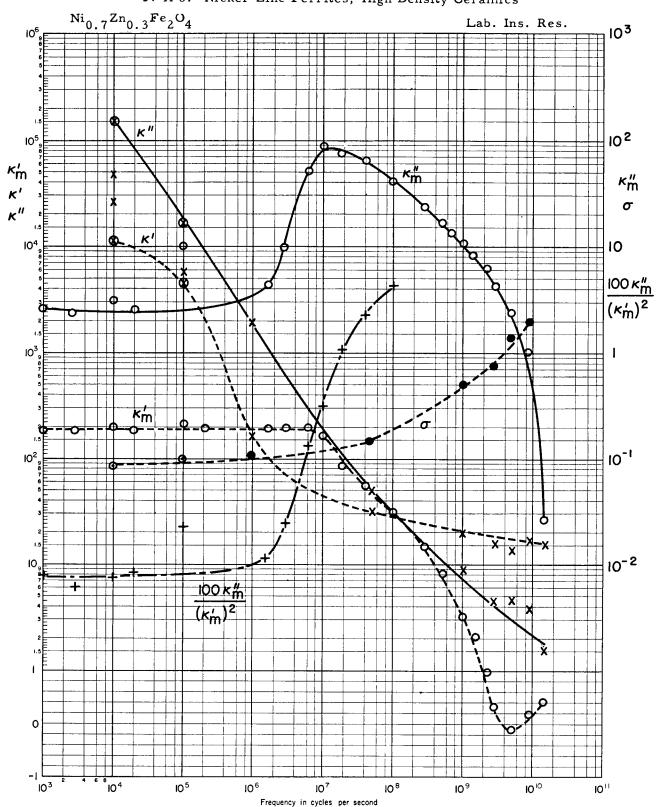
IV A 8. Nickel-Zinc Ferrites, High Density Ceramics



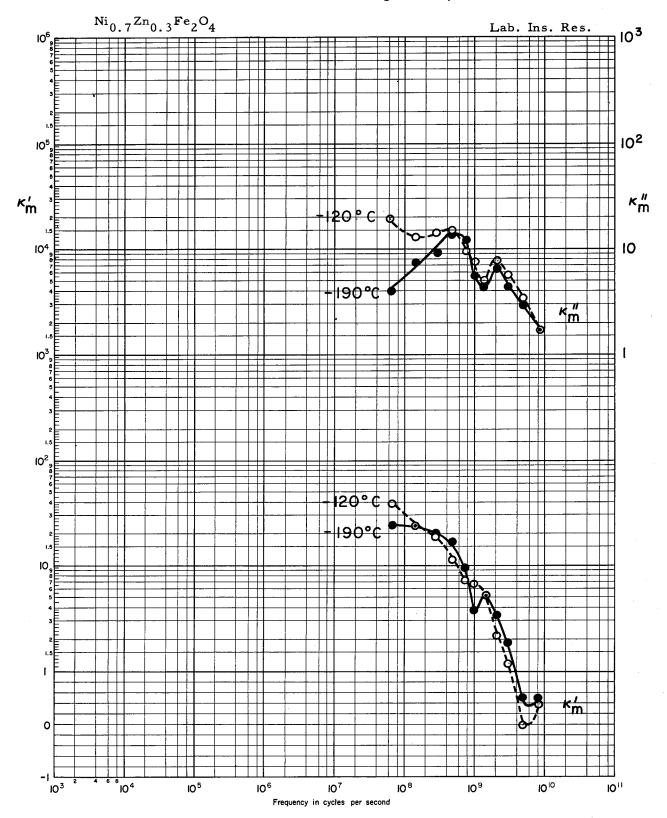


IV A 8. Nickel-Zinc Ferrites, High Density Ceramics

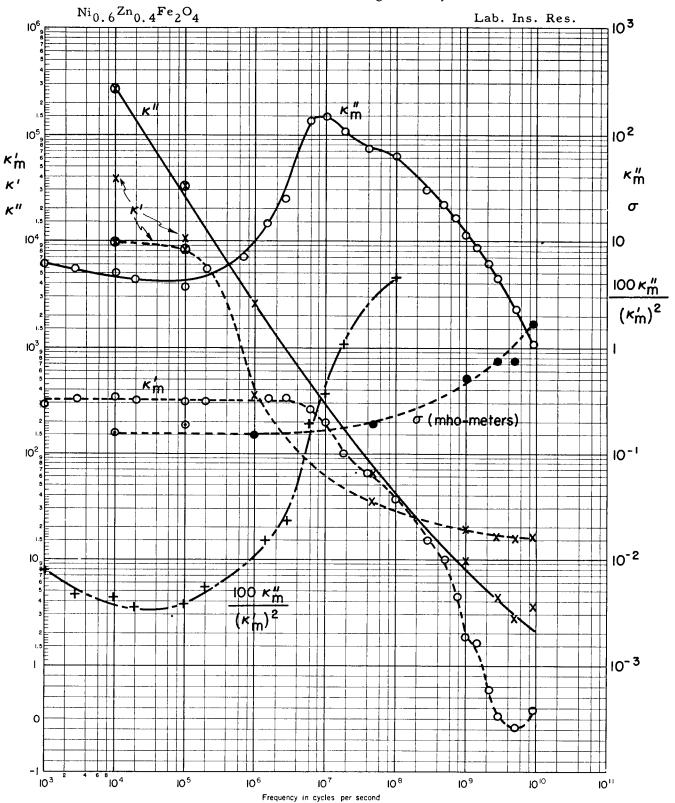




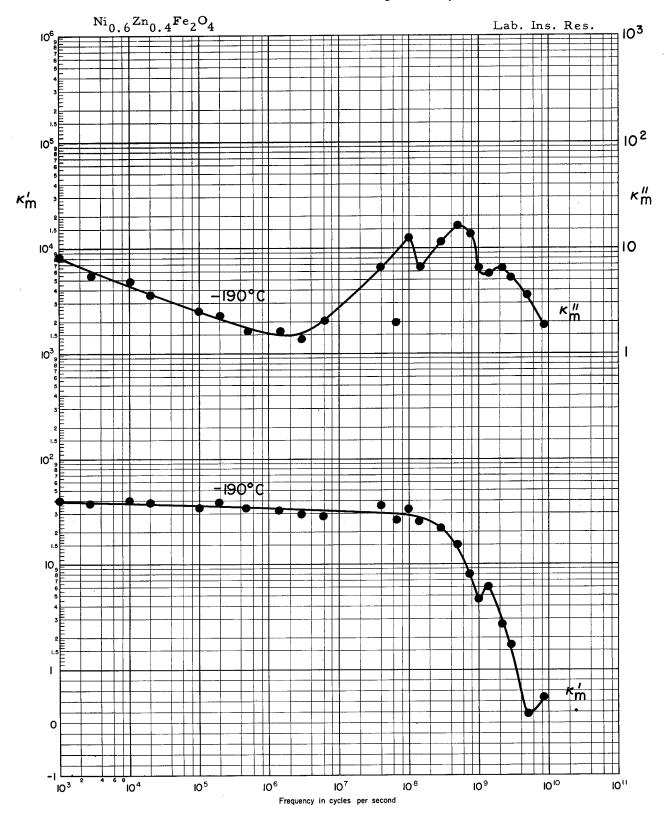
IV A 8. Nickel-Zinc Ferrites, High Density Ceramics



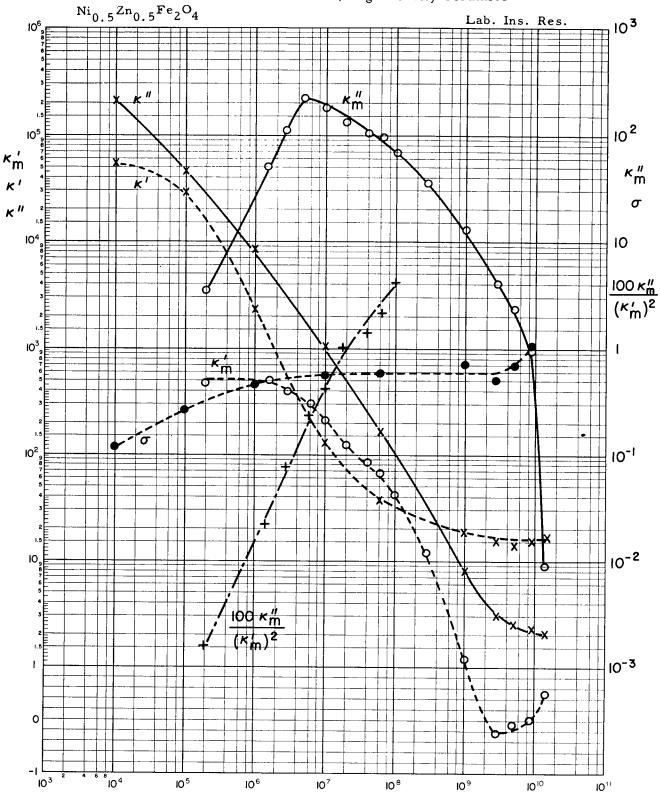
IV A 8. Nickel-Zinc Ferrites, High Density Ceramics



IV A 8. Nickel-Zinc Ferrites, High Density Ceramics

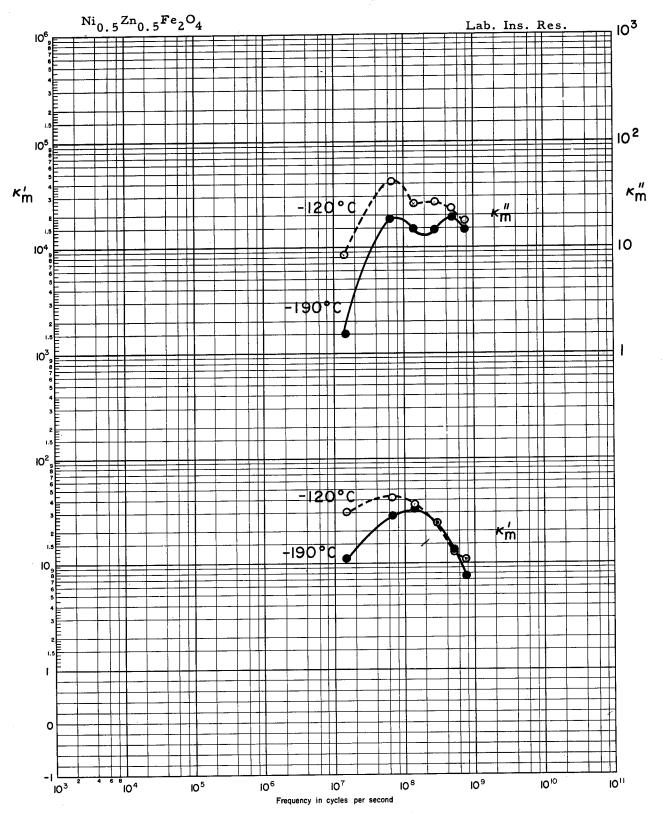


- 152 - IV A 8. Nickel-Zinc Ferrites, High Density Ceramics

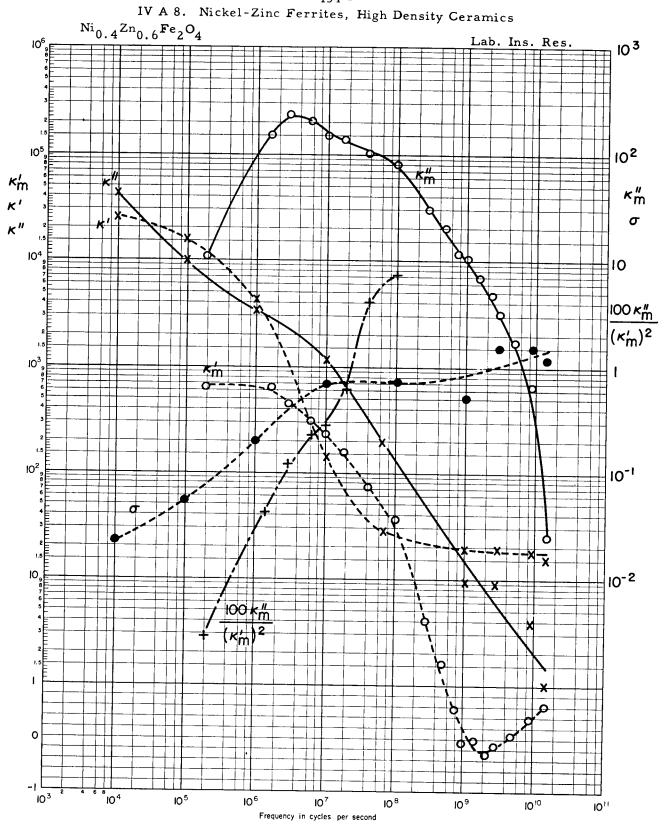


Frequency in cycles per second

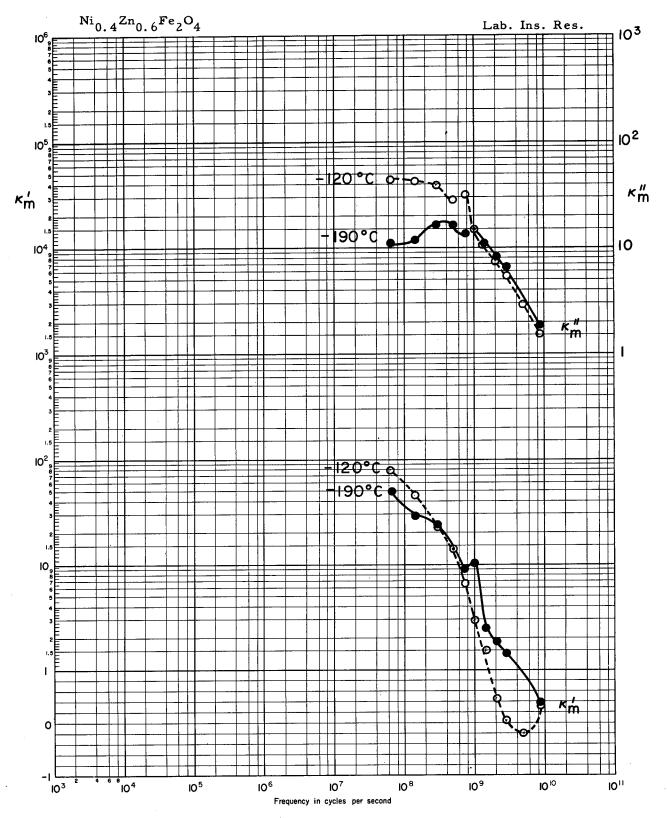
IV A.8. Nickel-Zinc Ferrites, High Density Ceramics



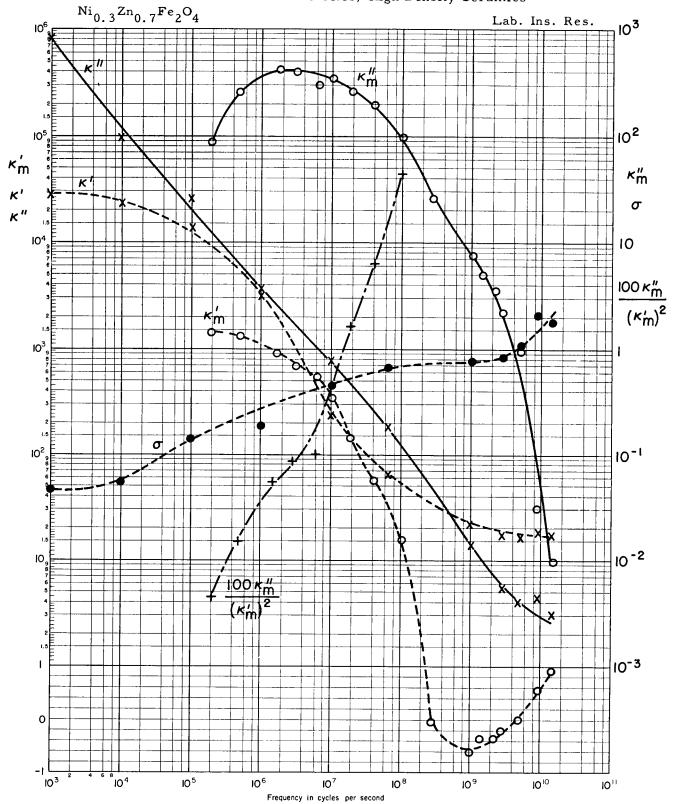
- 154 -



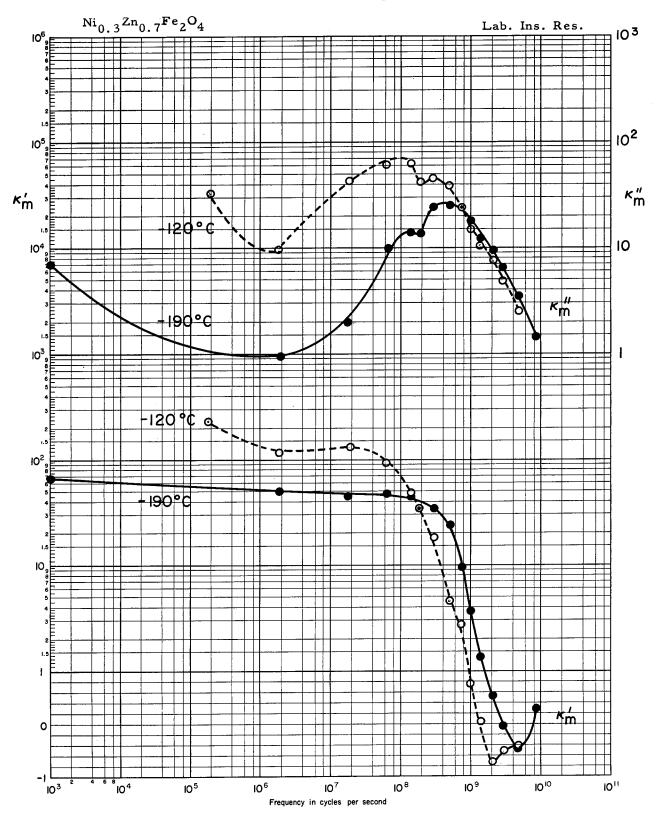
IV A 8. Nickel-Zinc Ferrites, High Density Ceramics



IV A 8. Nickel-Zinc Ferrites, High Density Ceramics

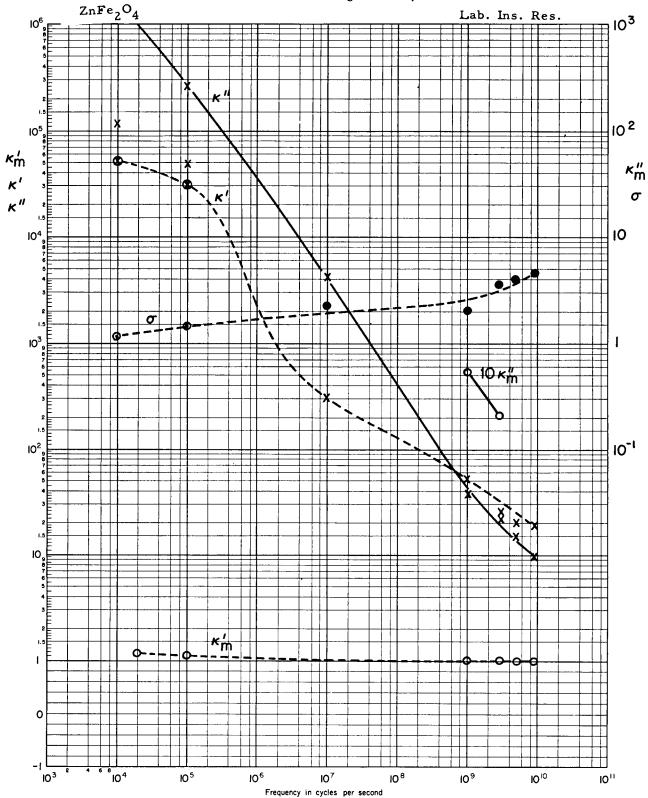


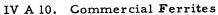
IV A 8. Nickel-Zinc Ferrites, High Density Ceramics

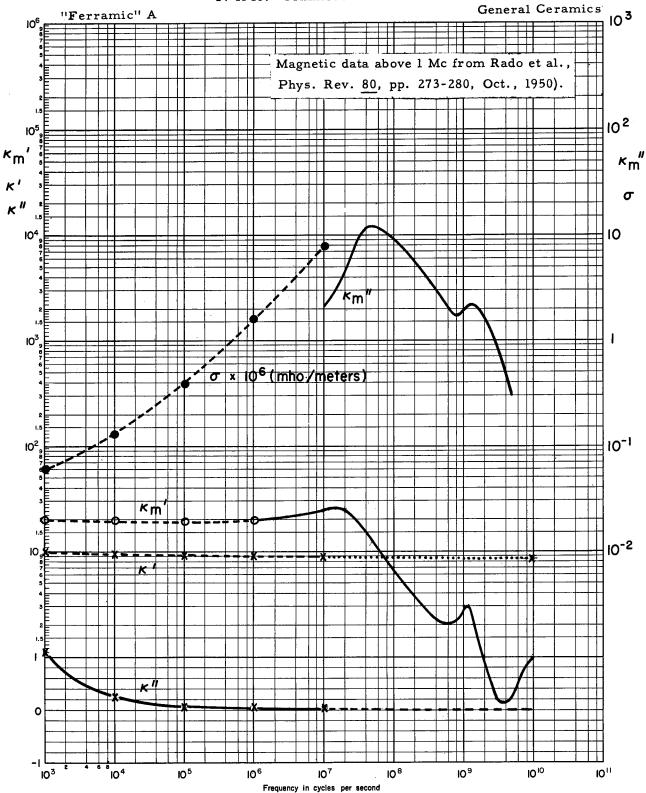


- 158 -

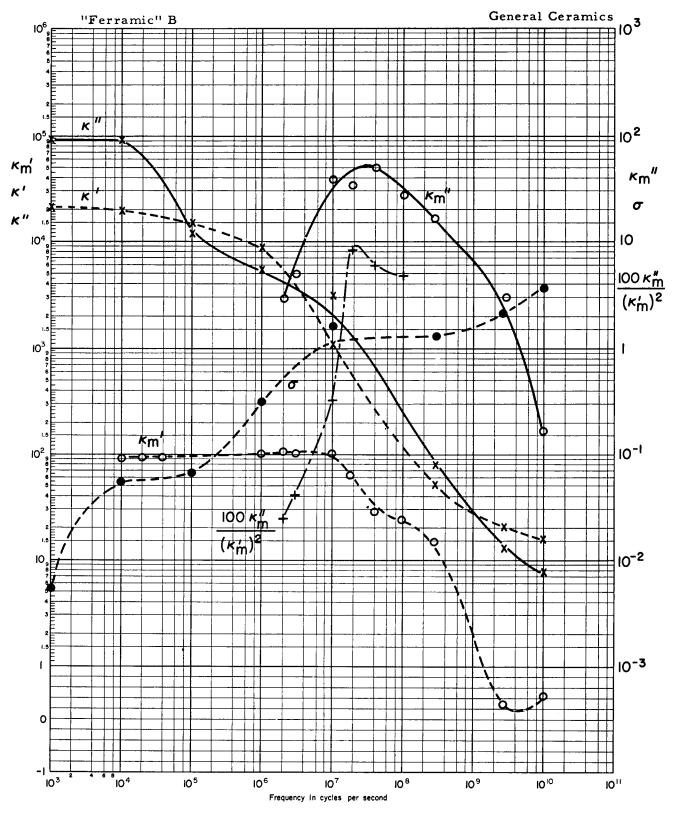
IV A 9. Zinc Ferrite, High Density Ceramic



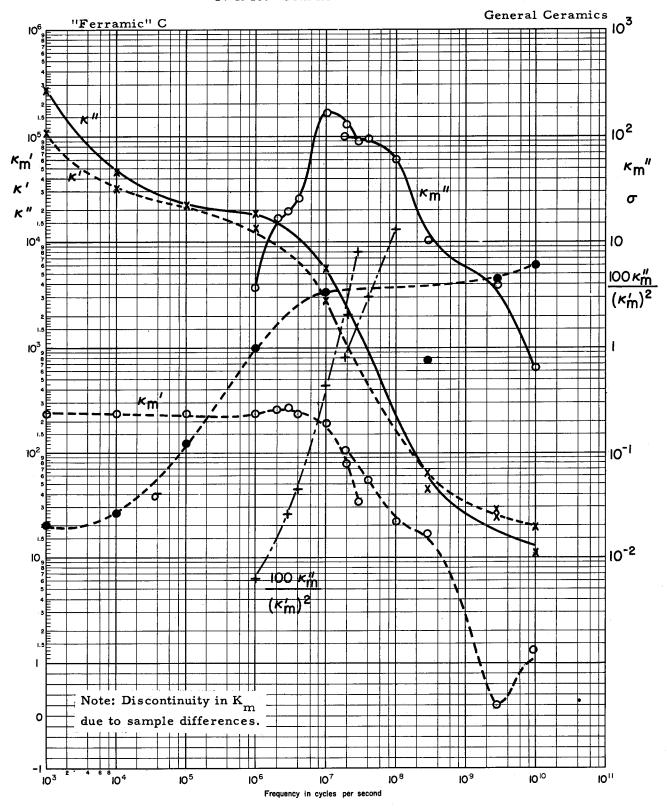




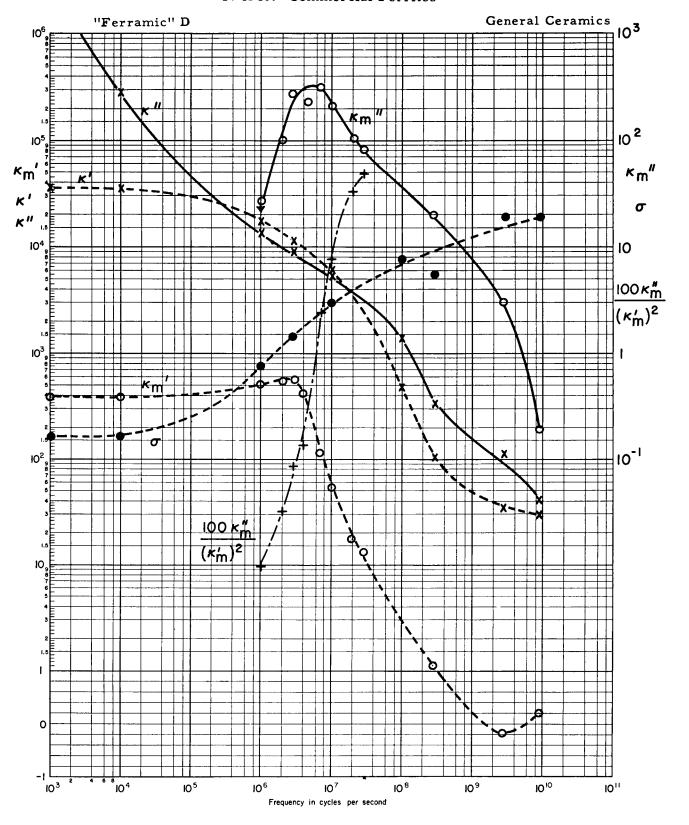
IV A 10. Commercial Ferrites

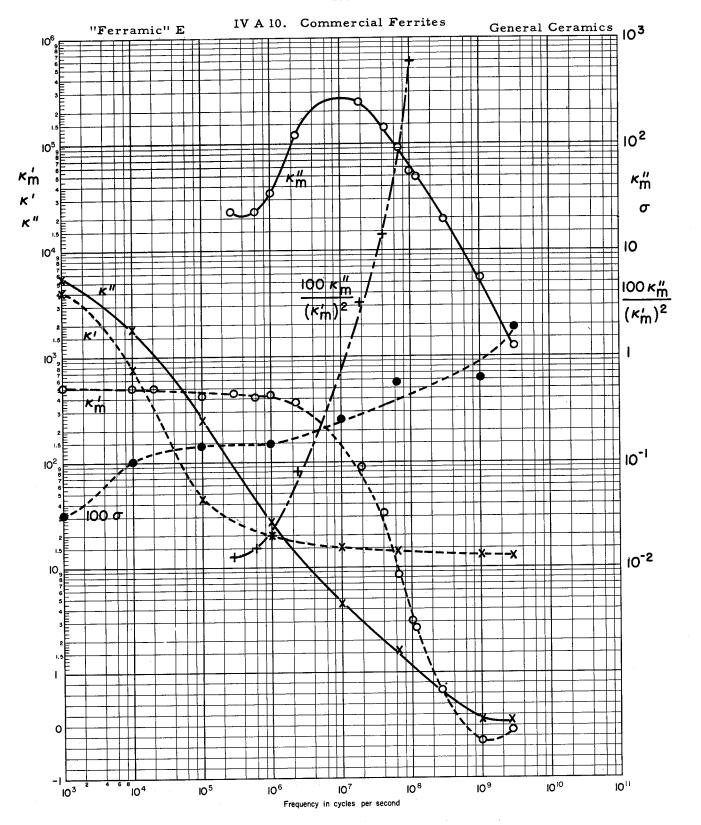


IV A 10. Commercial Ferrites

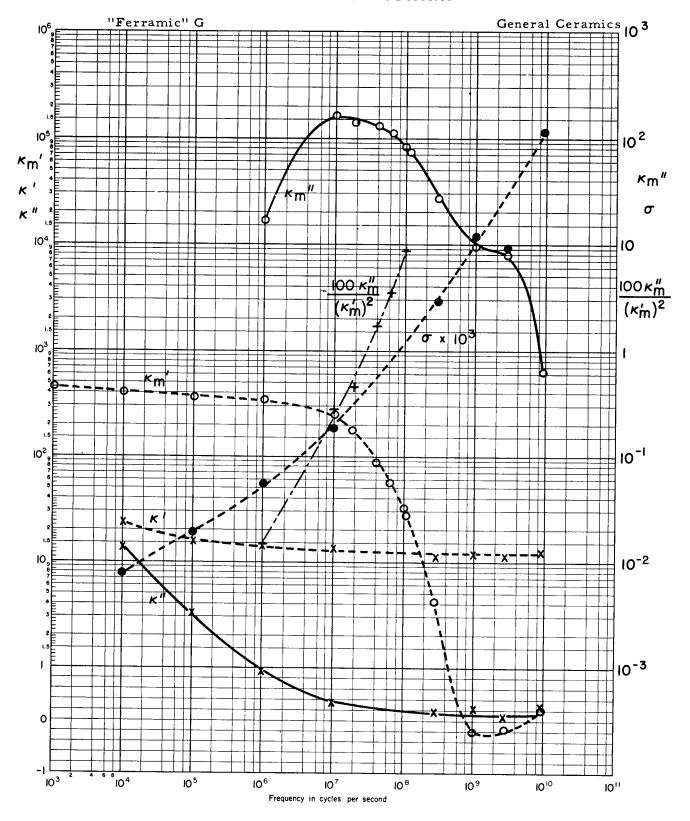


IV A 10. Commercial Ferrites

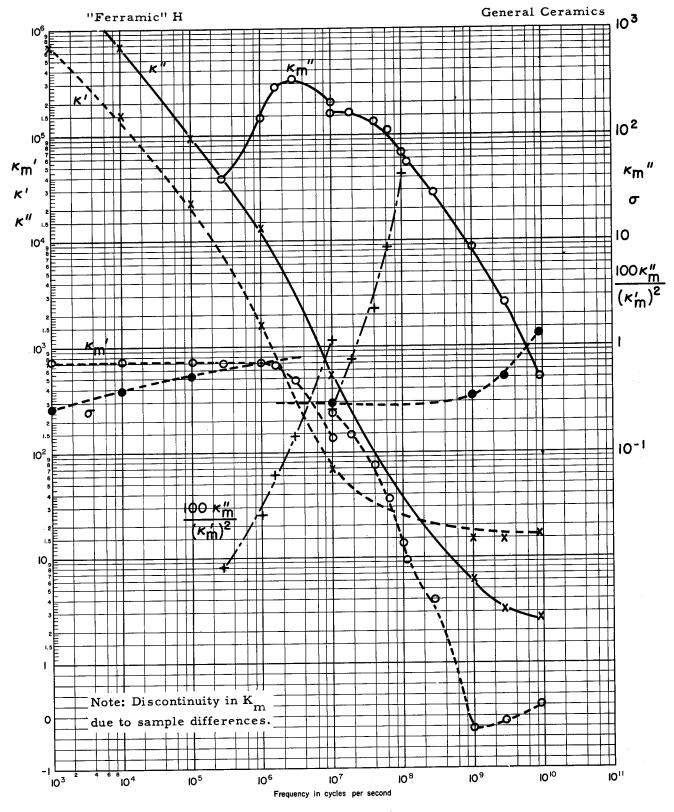




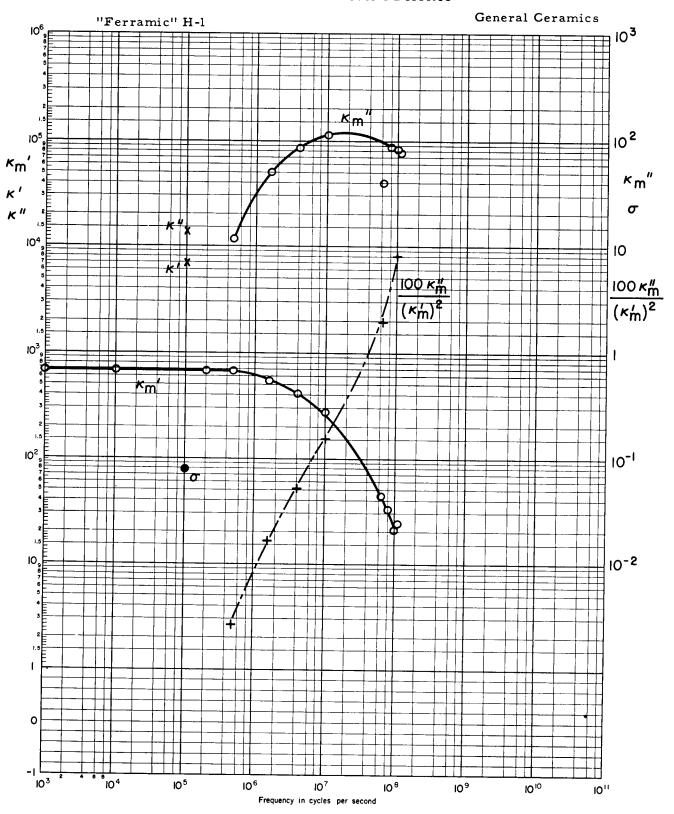
IV A 10. Commercial Ferrites



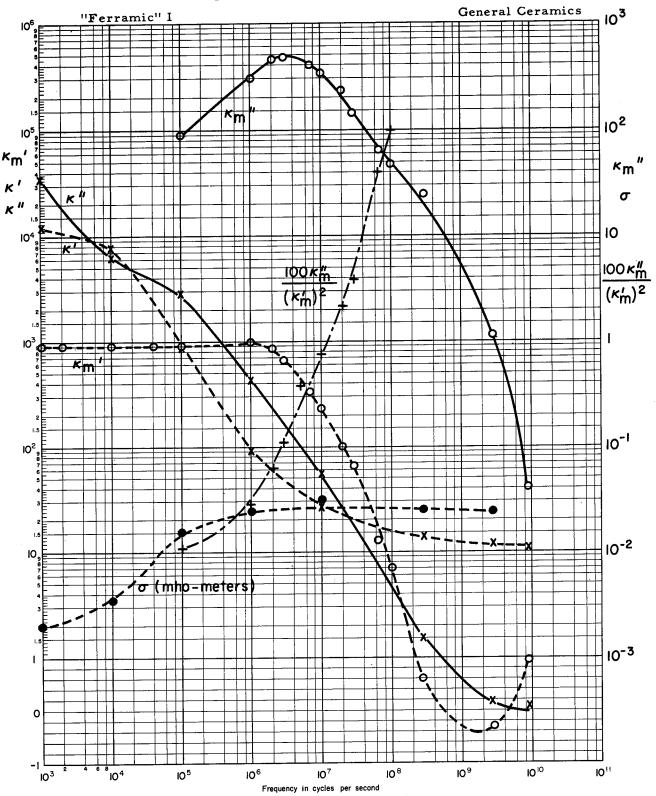
IV A 10. Commercial Ferrites



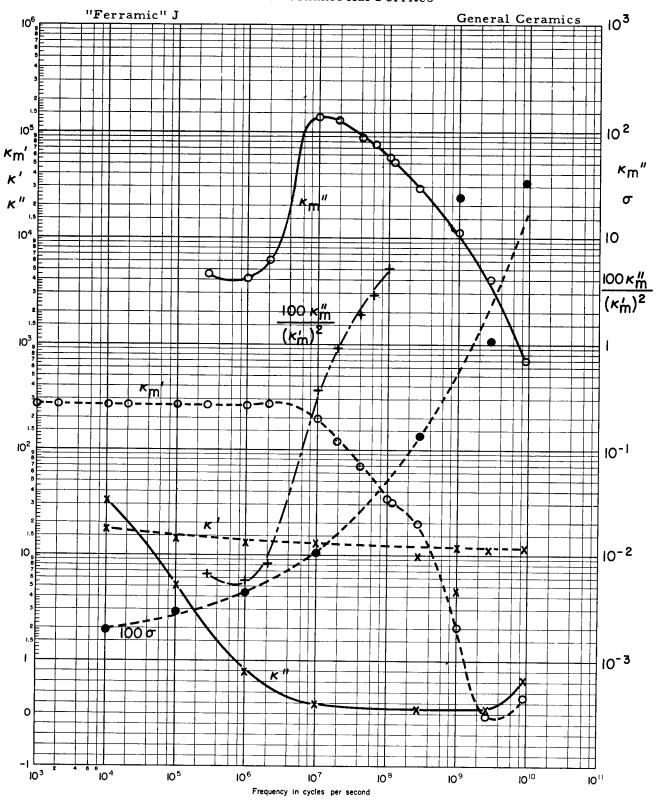
IV A 10. Commercial Ferrites



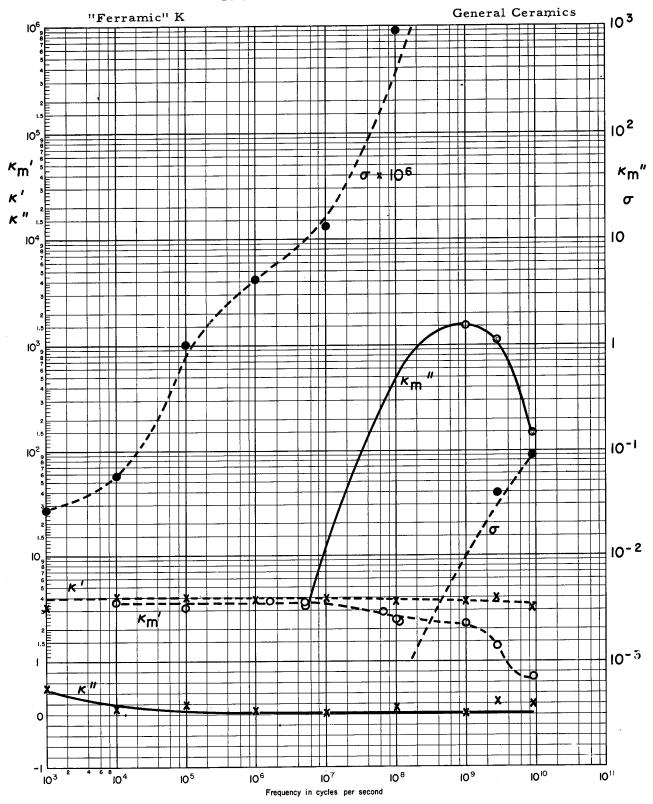
IV A 10. Commercial Ferrites



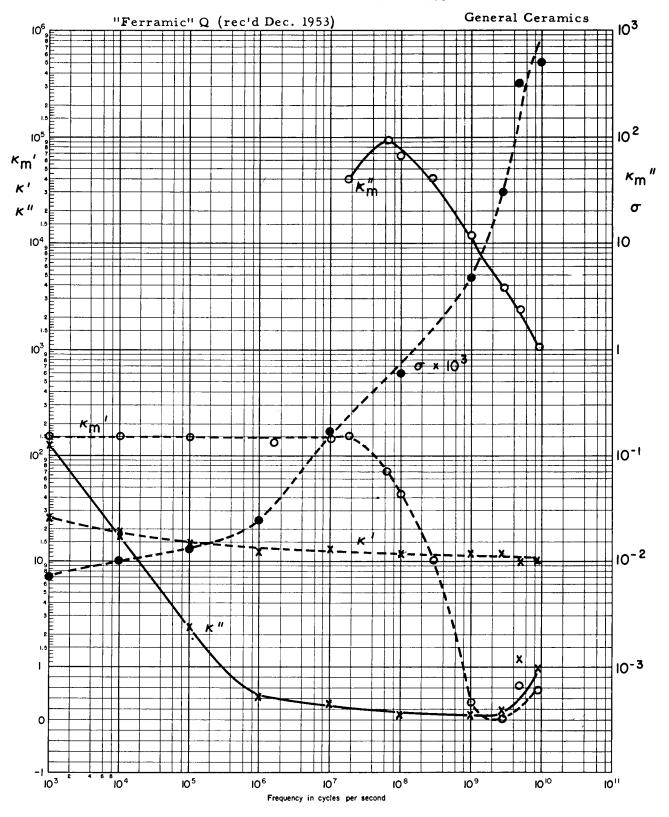
IV A 10. Commercial Ferrites

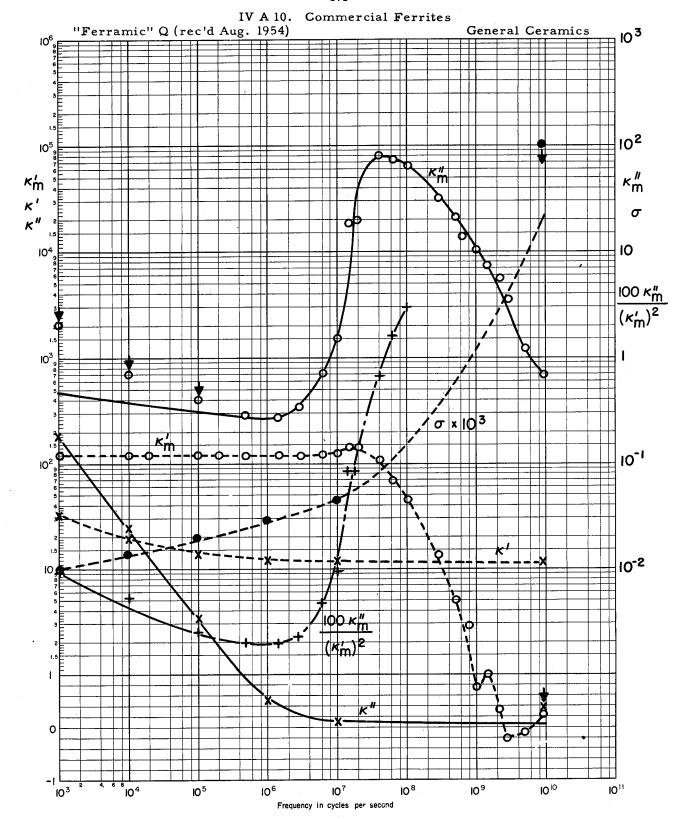


IV A 10. Commercial Ferrites

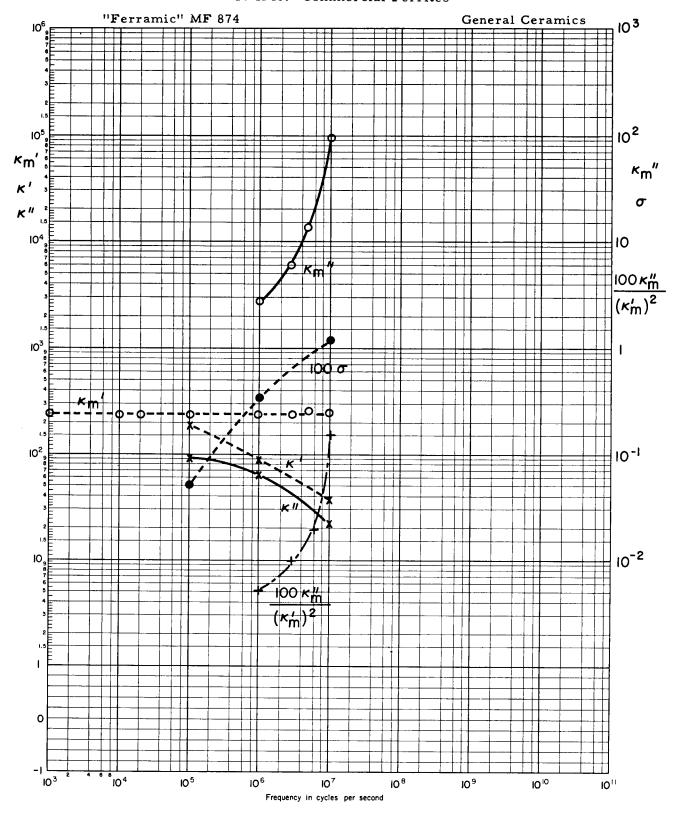


IV A 10. Commercial Ferrites

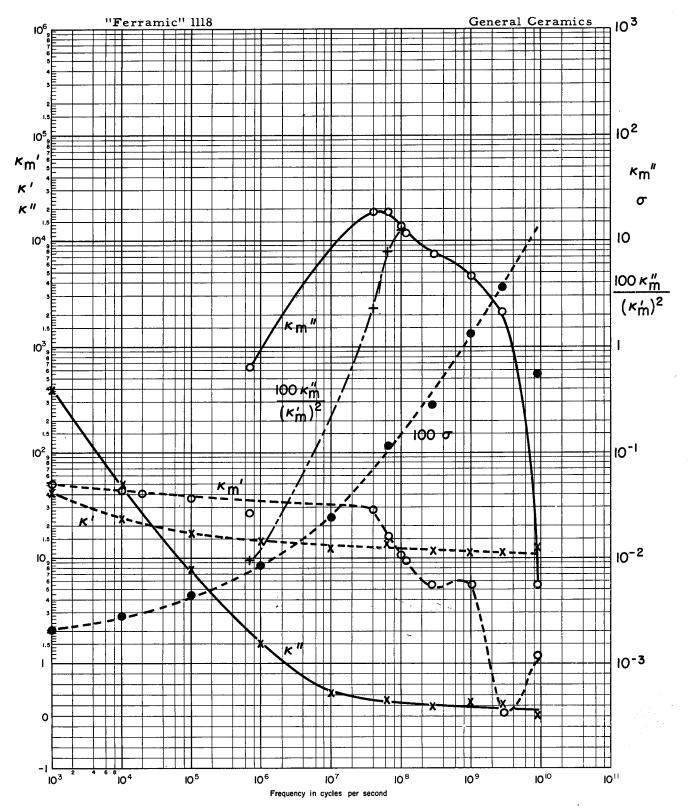




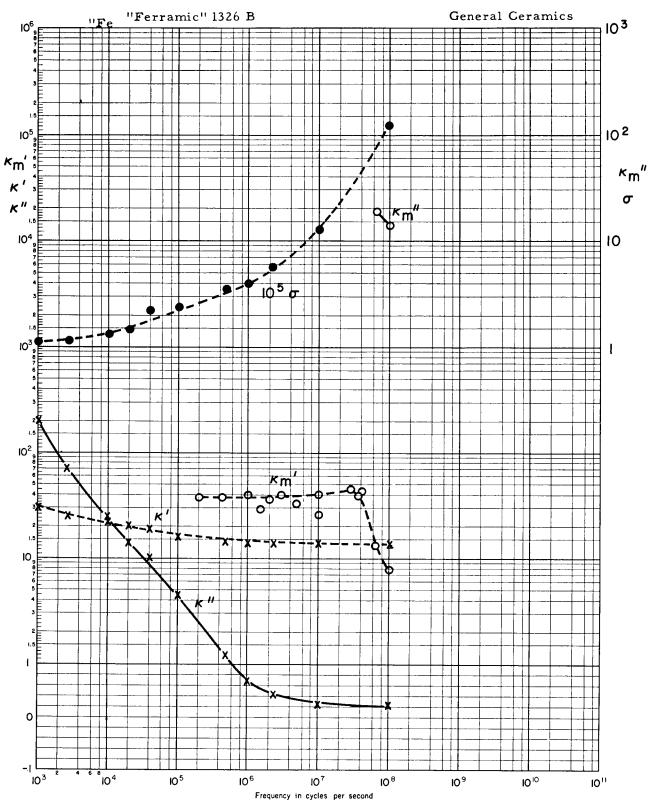
IV A 10. Commercial Ferrites



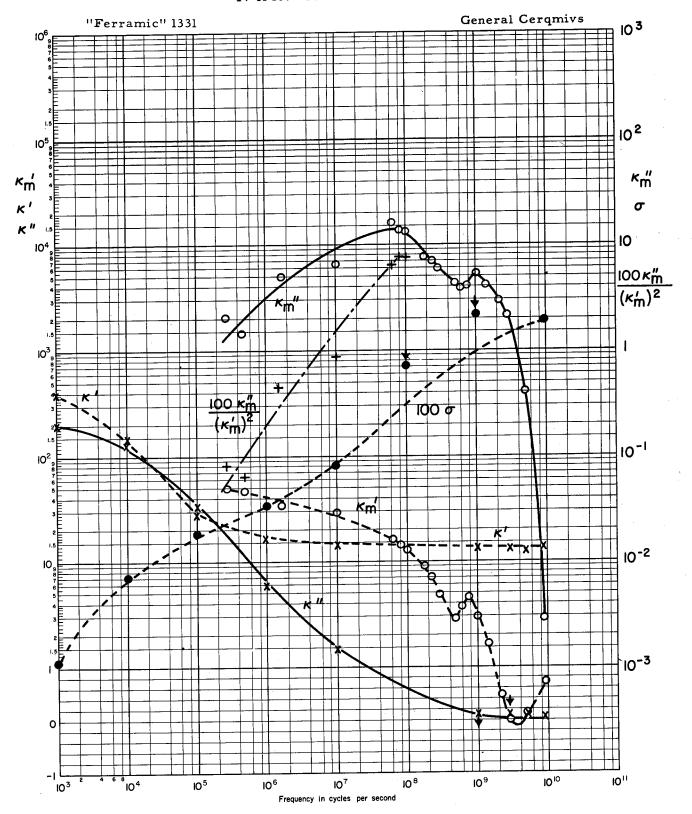
IV A 10. Commercial Ferrites

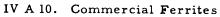


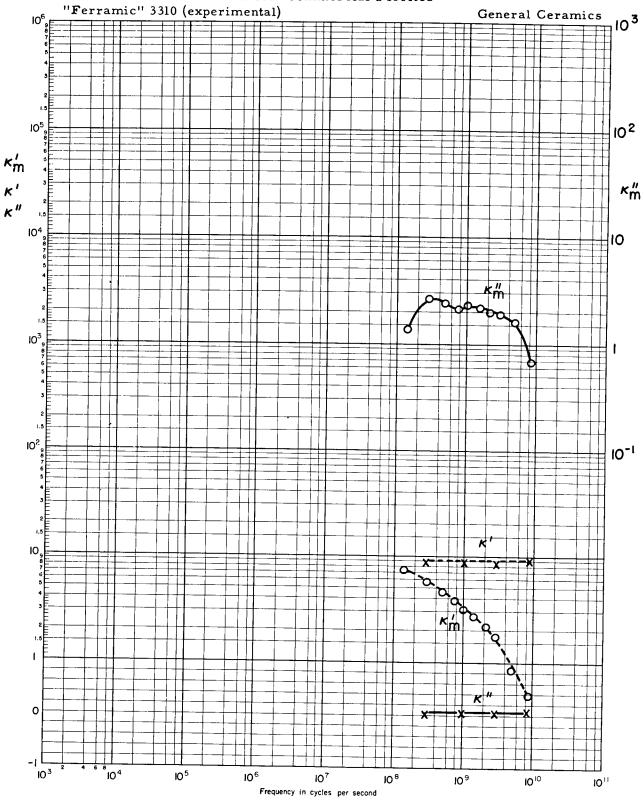
IV A 10. Commercial Ferrites



IV A 10. Commercial Ferrites

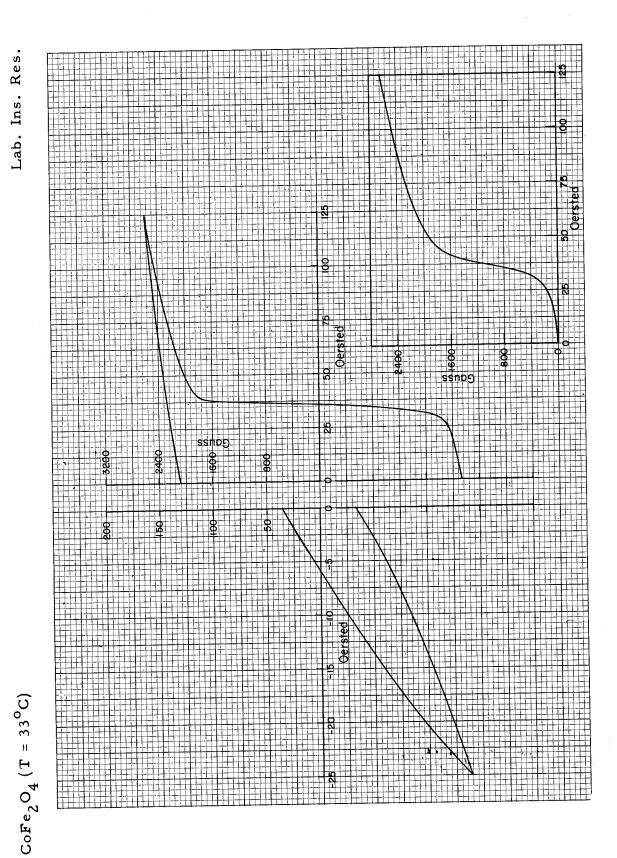




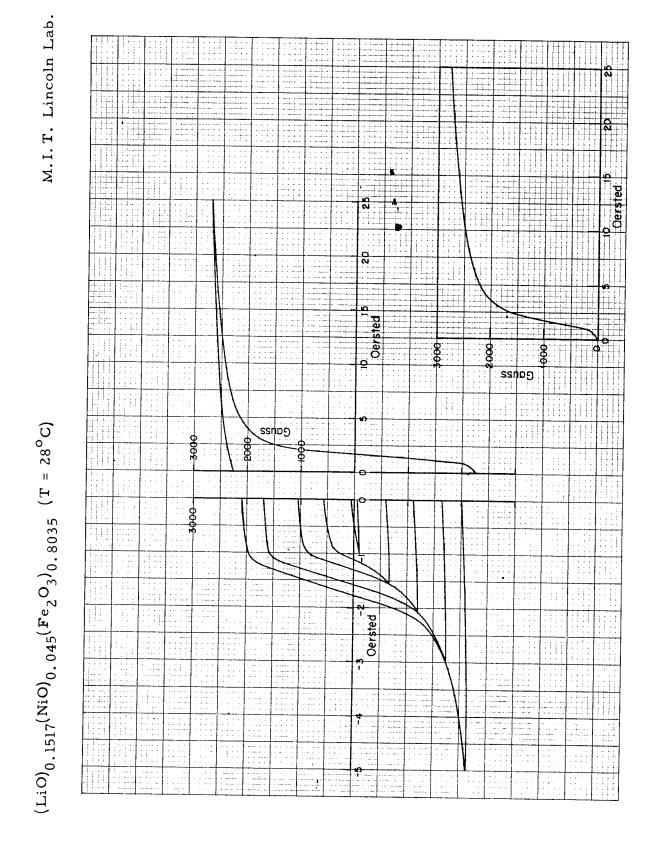


IV B. Hysteresis Loops and Saturation Magnetization

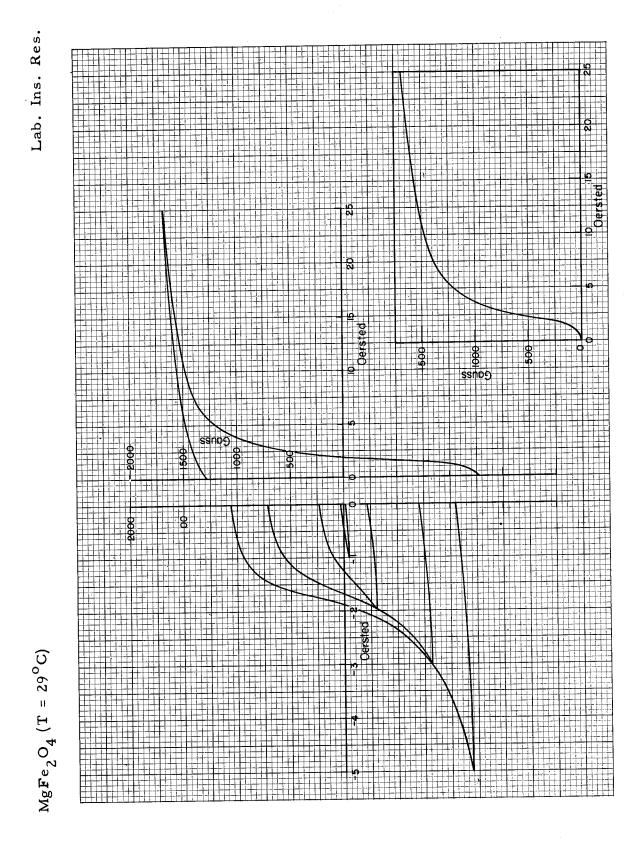
1. Cobalt Ferrite, High Density Ceramic



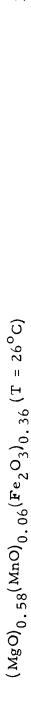
IV B 2. Lithium-Nickel Ferrite Ceramic

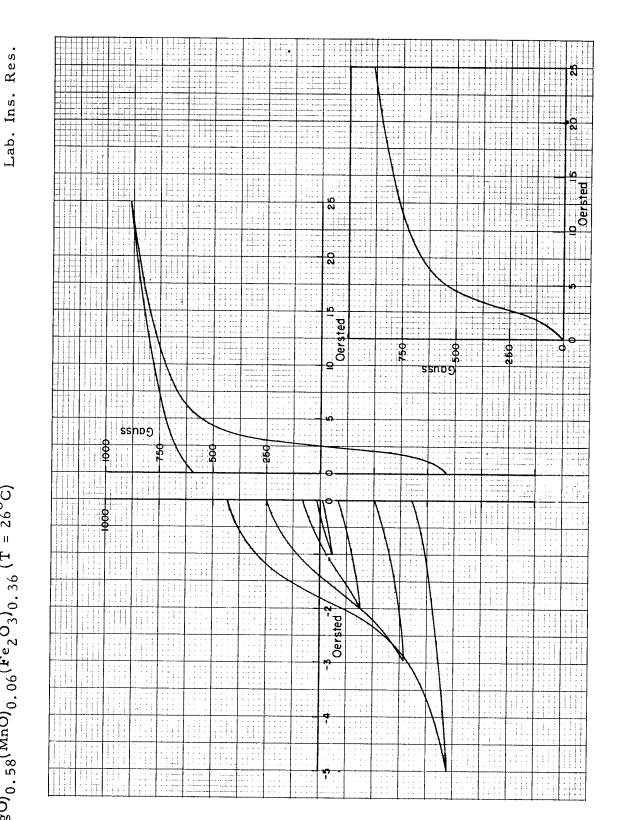


IV B 3. Magnesium Ferrite, High Density Ceramic

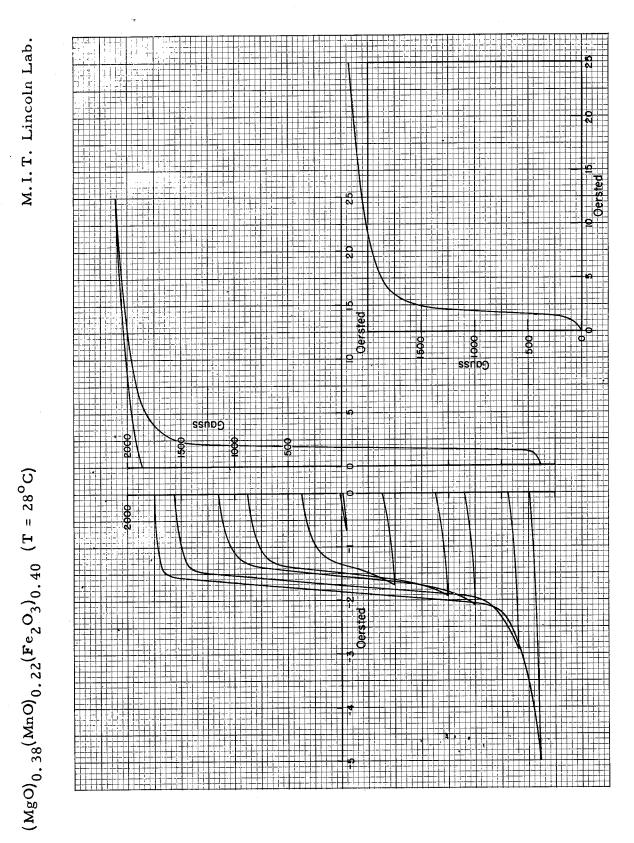


IV B 4. Magnesium-Manganese Ferrite Ceramics



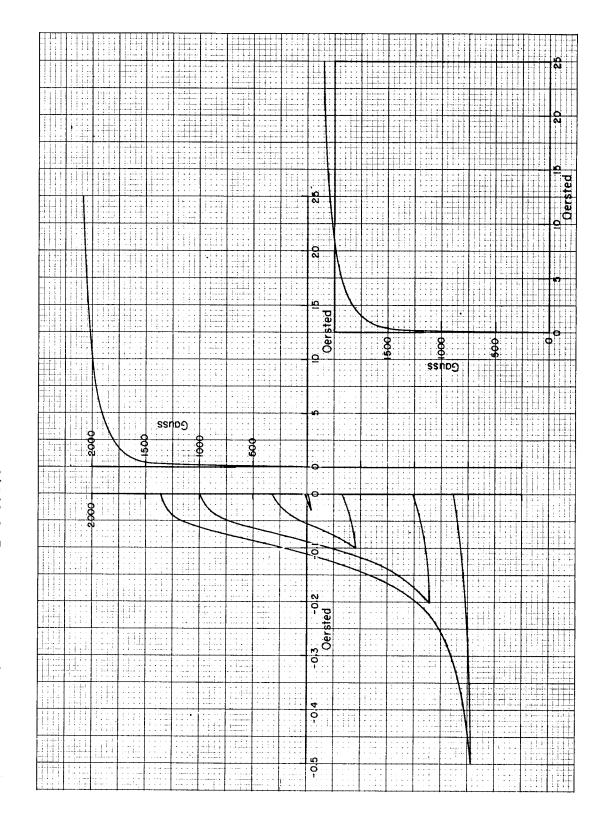


IV B 4. Magnesium-Manganese Ferrite Ceramics

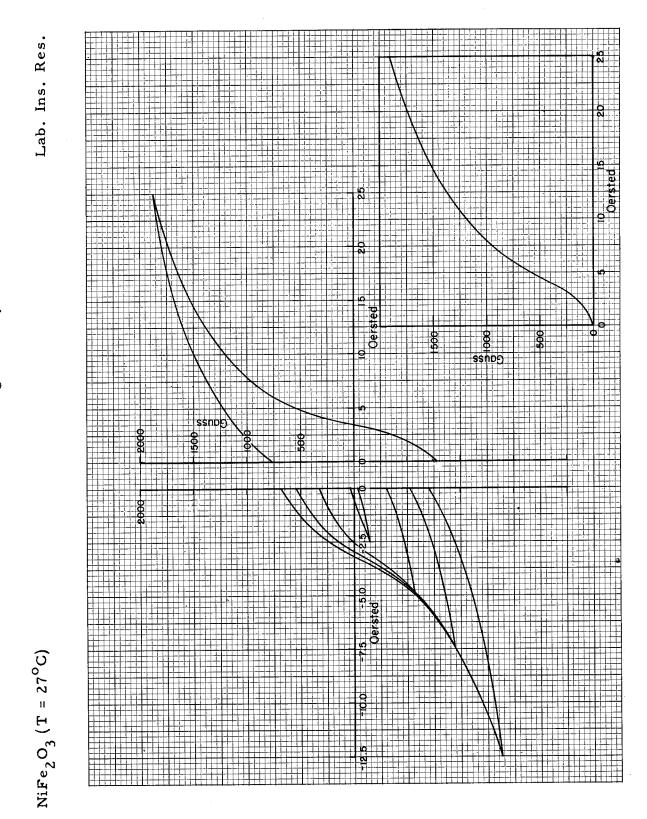


IV B 5. Magnesium-Manganese-Zinc Ferrite Ceramic

M.I.T. Lincoln Lab. $(MgO)_{0.174}(MnO)_{0.209}(ZnO)_{0.221}(Fe_2O_3)_{0.395}$ (T = 28°C)



IV B 6. Nickel Ferrite, High Density Ceramic

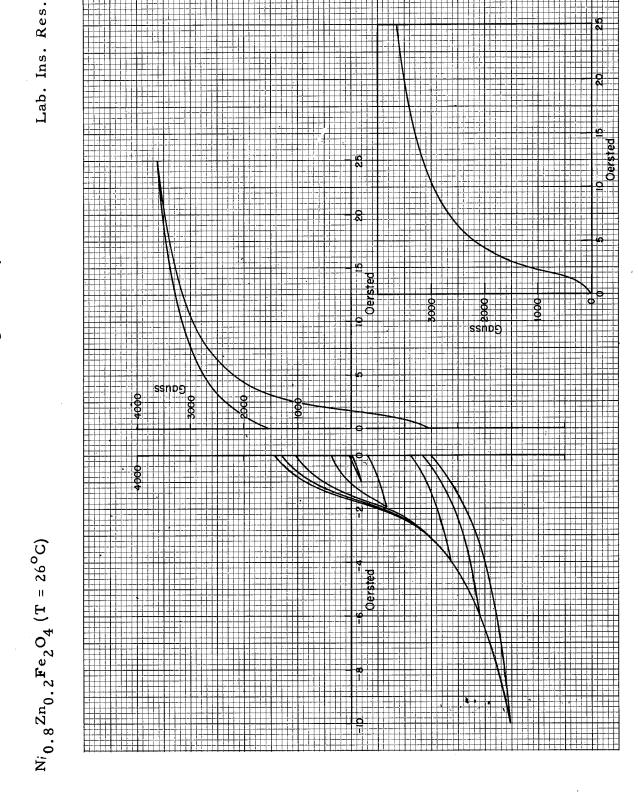


IV B 7. Nickel-Zinc Ferrite, High Density Ceramics

 $Ni_{0.9}^{2n_{0.1}}$ Fe $_2^{2o_4}$ (T = 26°C)

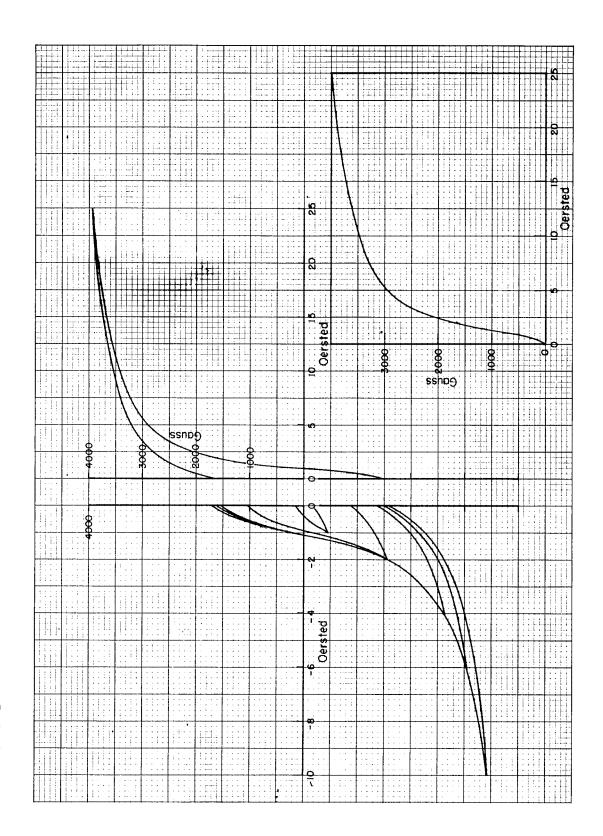
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IV B 7. Nickel-Zinc Ferrite, High Density Ceramics



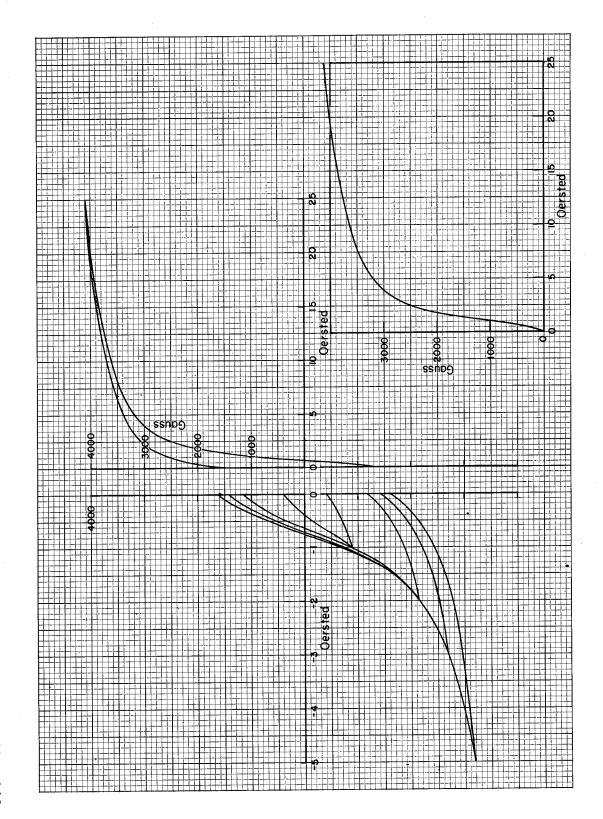
IV B 7. Nickel-Zinc Ferrite, High Density Ceramics

 $Ni_{0.7}Zn_{0.3}Fe_2O_4$ (T = 26°C)



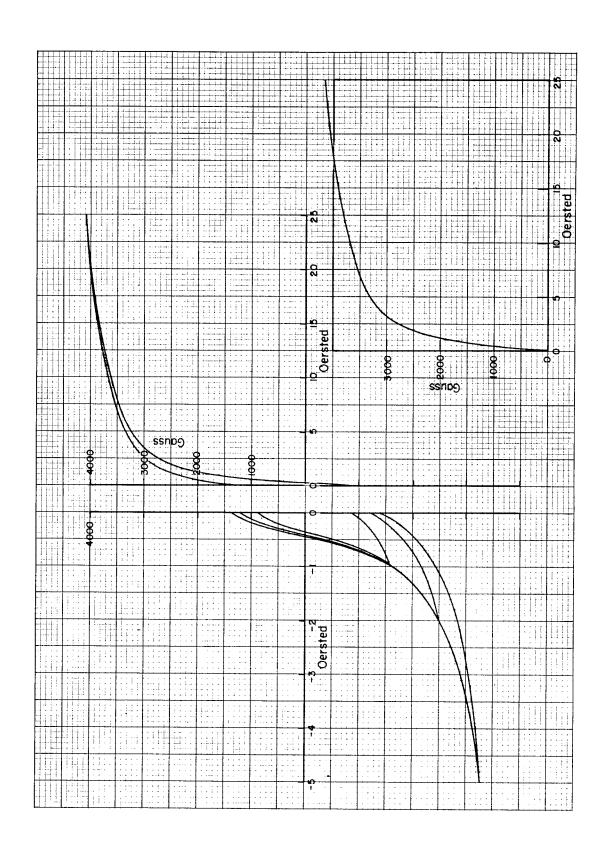
IV B 7. Nickel-Zinc Ferrite, High Density Ceramics





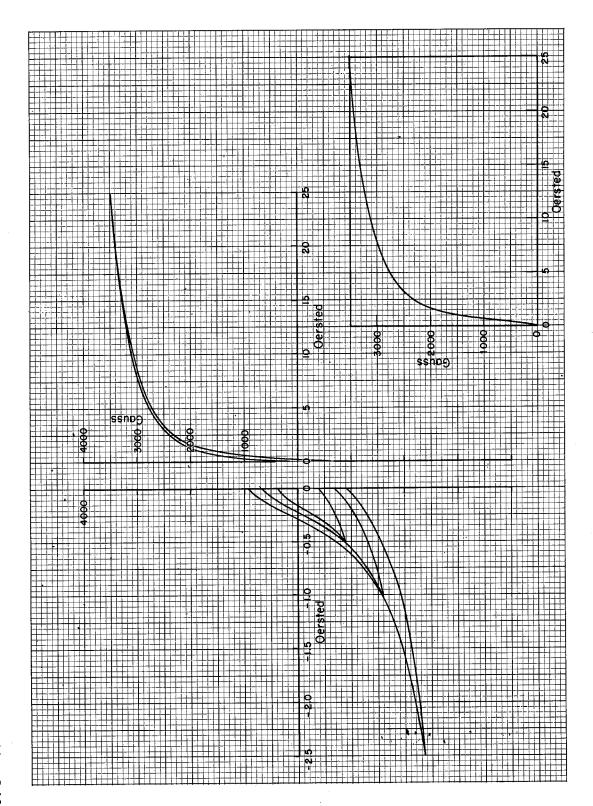
IV B 7. Nickel-Zinc Ferrite, High Density Ceramics

 $Ni_{0.5}Zn_{0.5}Fe_2O_4$ (T = 26°C)



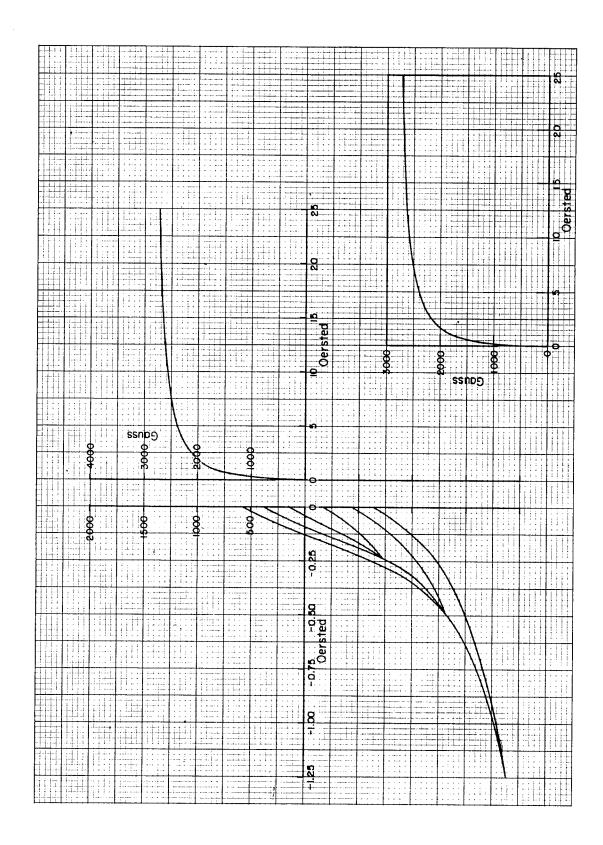
IV B 7. Nickel-Zinc Ferrite, High Density Ceramics



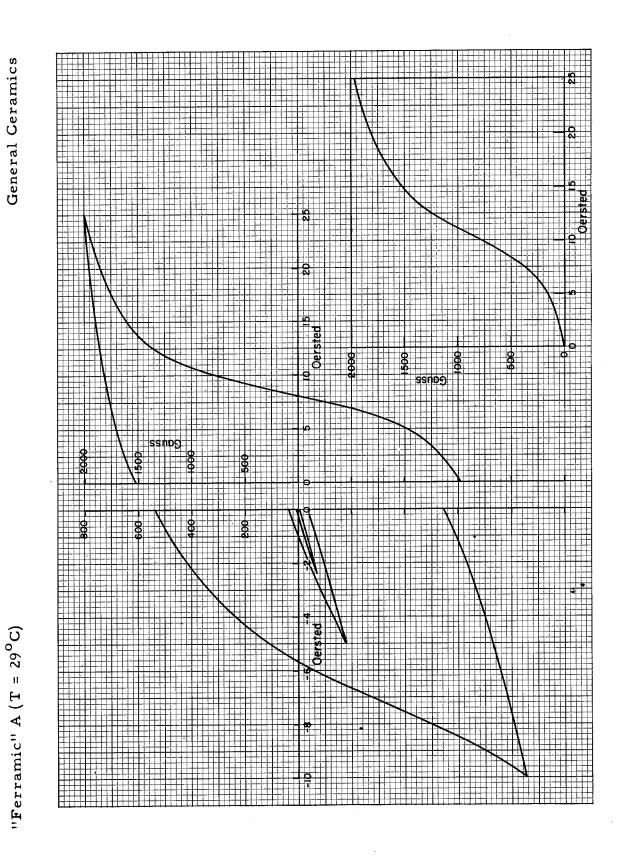


IV B 7. Nickel-Zinc Ferrite, High Density Ceramics

 $Ni_{0.3}Zn_{0.7}Fe_2O_4$ (T = 29°C)

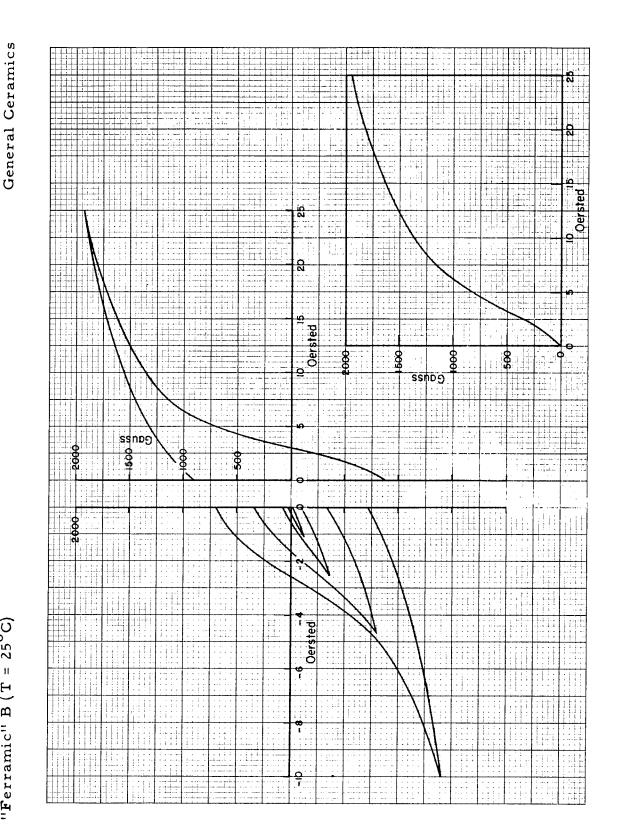


IV B 8. Commercial Ferrite Ceramics

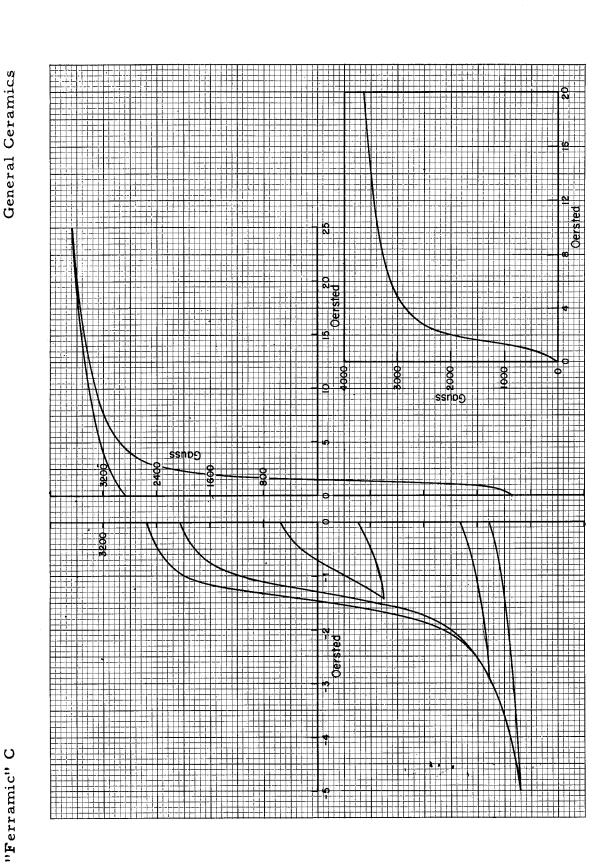


Commercial Ferrite Ceramics IV B 8.

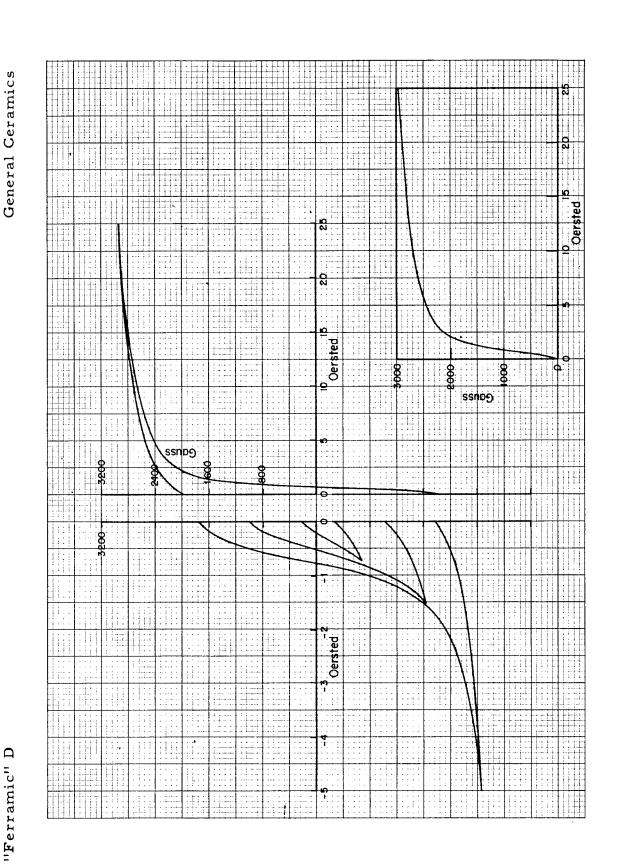
"Ferramic" $B(T = 25^{\circ}C)$



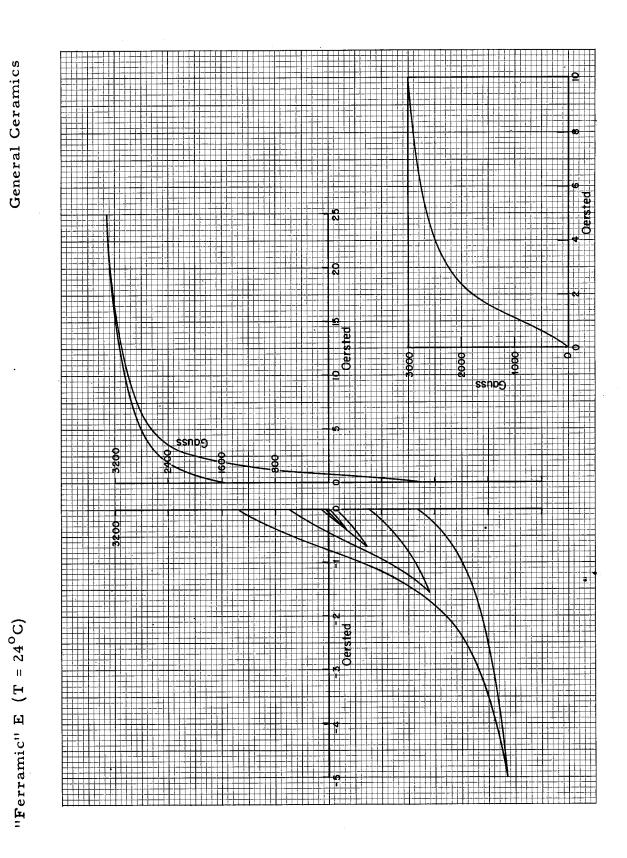
IV B 8. Commercial Ferrite Ceramics



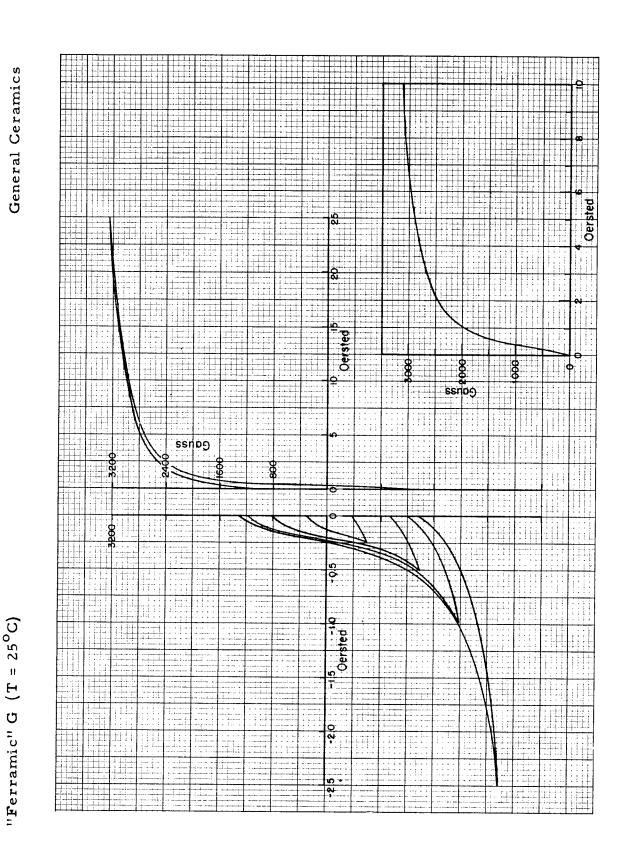
IV B 8. Commercial Ferrite Ceramics



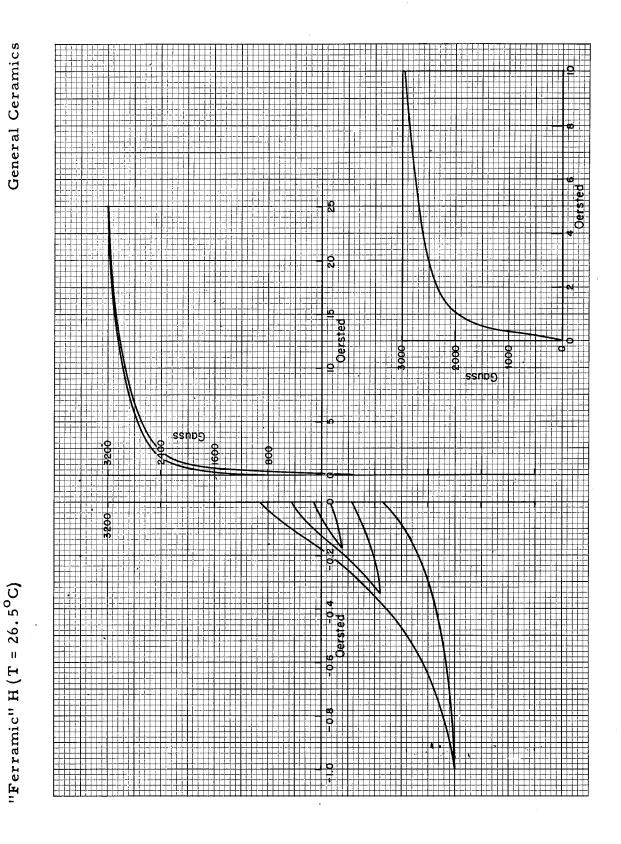
IV B 8. Commercial Ferrite Ceramics



IV B 8. Commercial Ferrite Ceramics



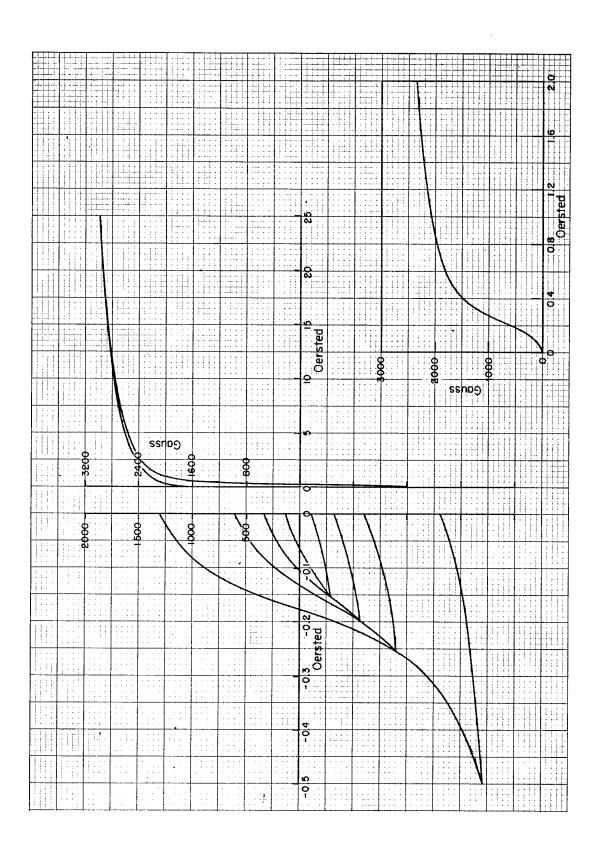
IV B 8. Commercial Ferrite Ceramics



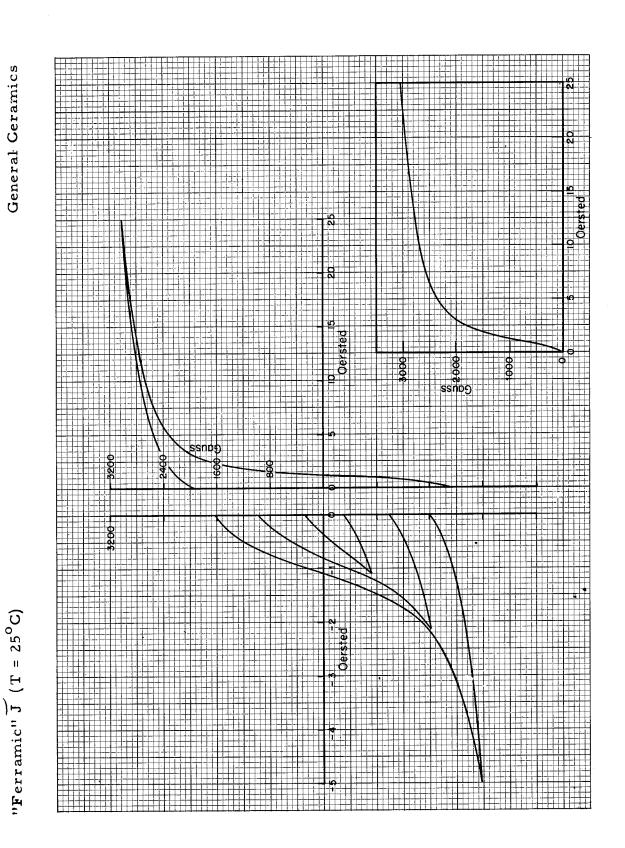
IV B 8. Commercial Ferrite Ceramics

"Ferramic" H-1 $(T = 27^{\circ}C)$

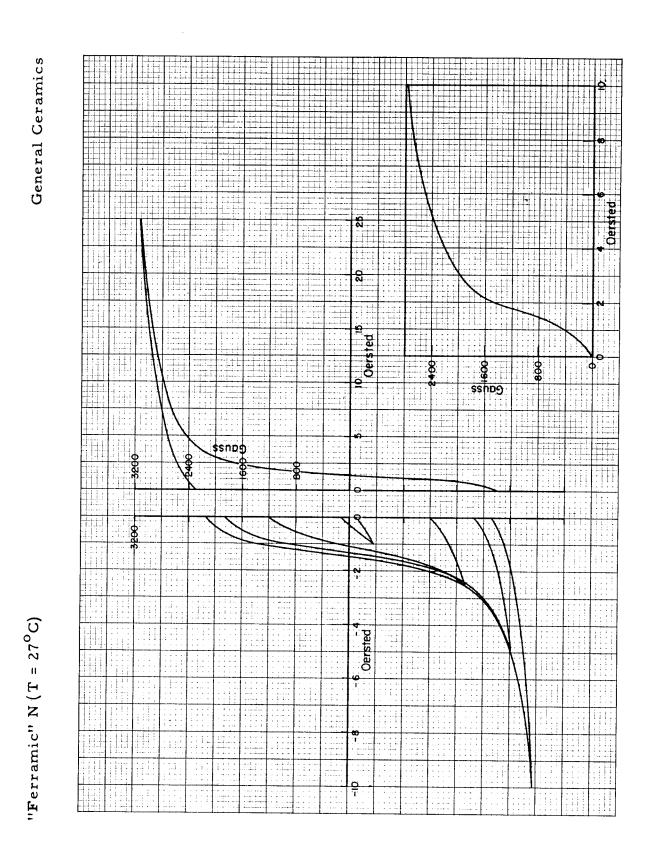
General Ceramics



IV B 8. Commercial Ferrite Ceramics

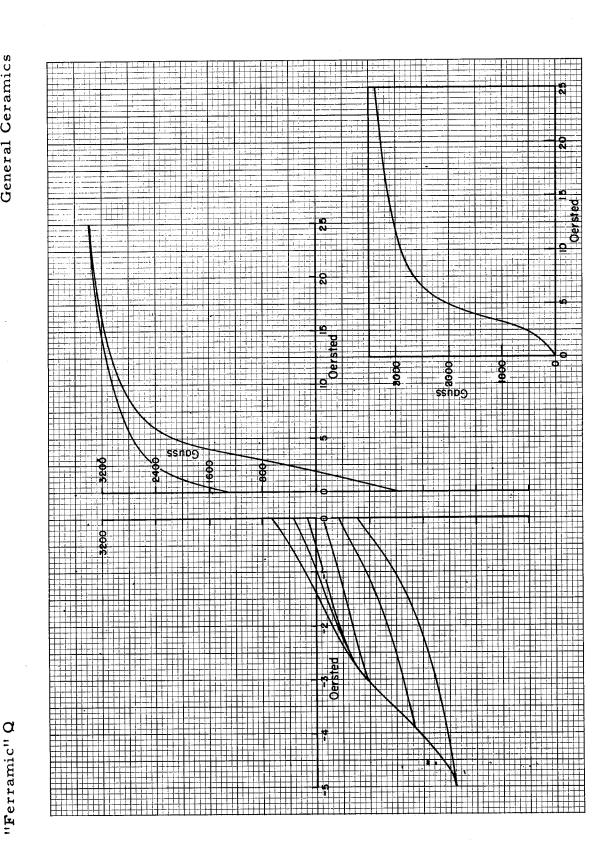


IV B 8. Commercial Ferrite Ceramics



Commercial Ferrite Ceramics IV B 8.

General Ceramics



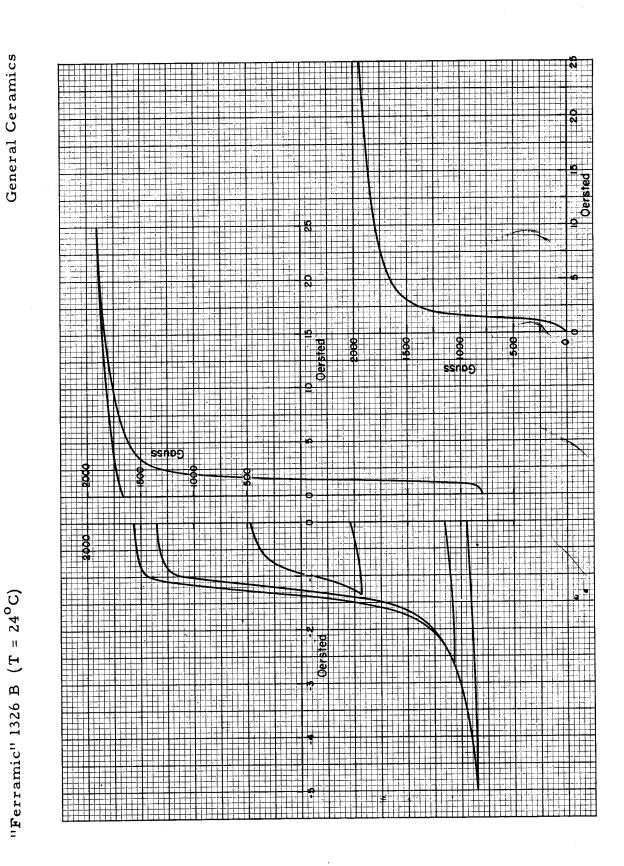
IV B 8. Commercial Ferrite Ceramics

"Ferramic" $MF 874 (T = 22^{\circ}C)$

General Ceramics

Oersted **10** Oersted Causs ssnog

IV B 8. Commercial Ferrite Ceramics



Oersted

IV B 8. Commercial Ferrite Ceramics

General Ceramics 8 • Causs \$SNDS 0 "Ferramic" 1331 (T = 25° C) Oersted 7//

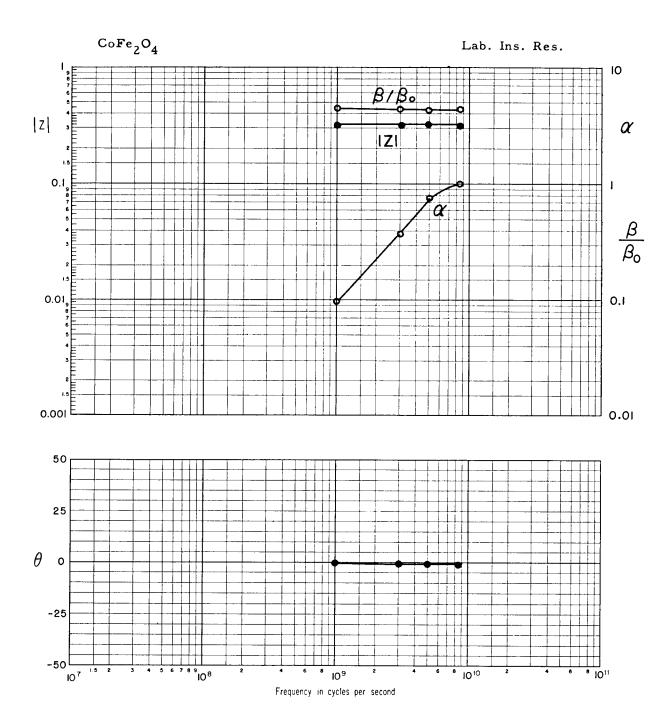
IV B 9. Magnetic-Plastic Mixture

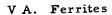
Polymer Corp. "Ferrotron" Core Material, Type 119

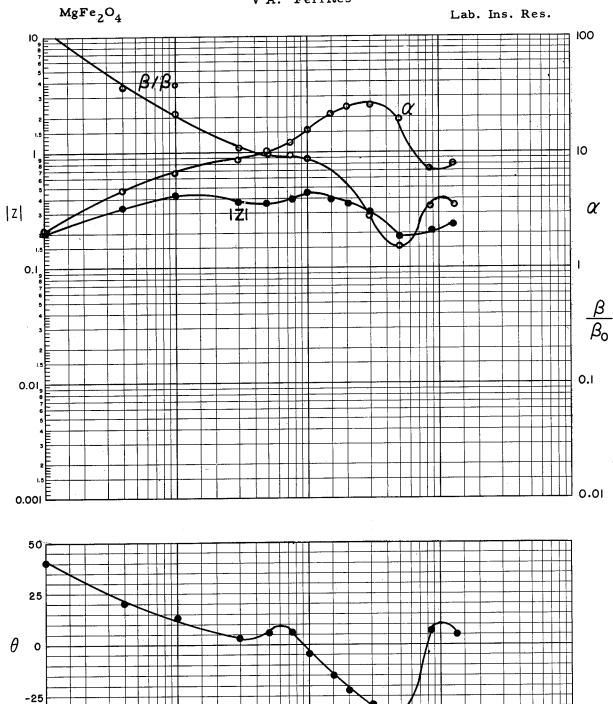
....

V. Attenuator Characteristics (Attenuation, Phase Shift, and Intrinsic Impedance)

A. Ferrites

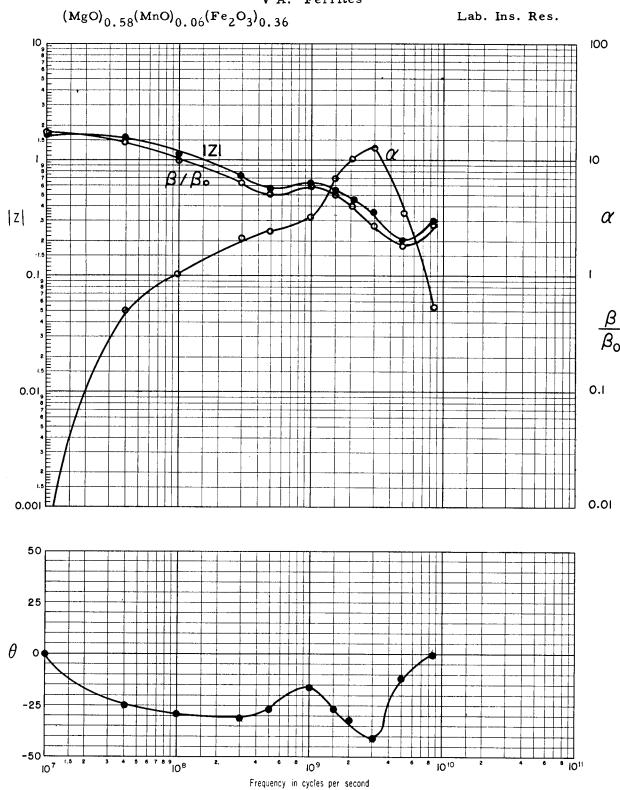


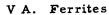


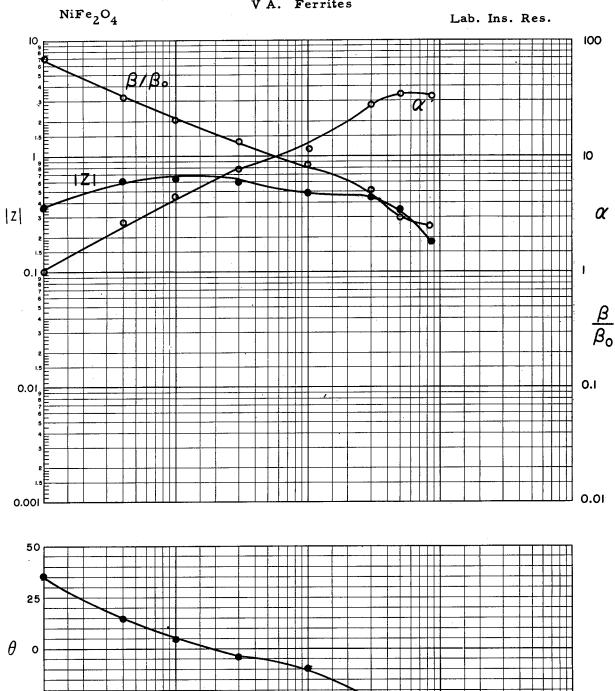


frequency in cycles per second

V A. Ferrites

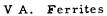


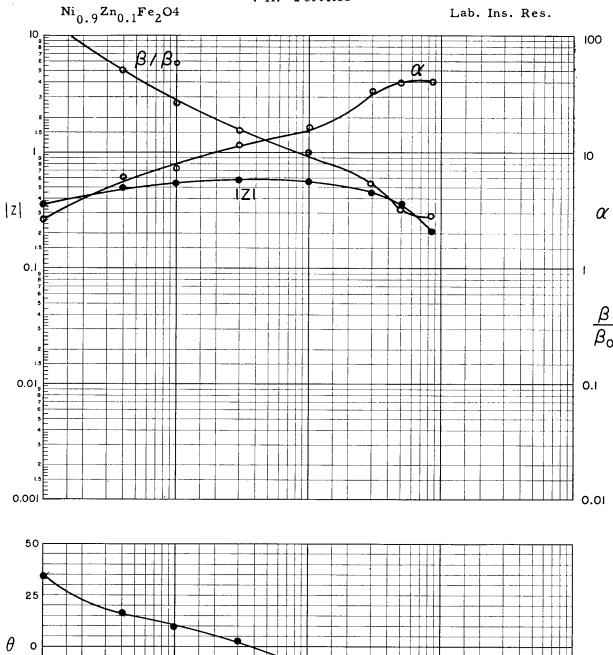


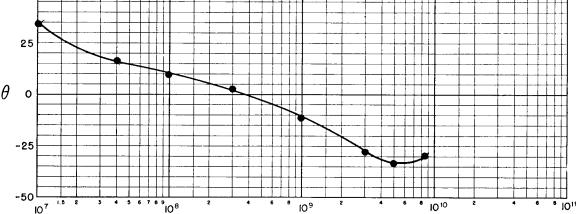


Frequency in cycles per second

-25

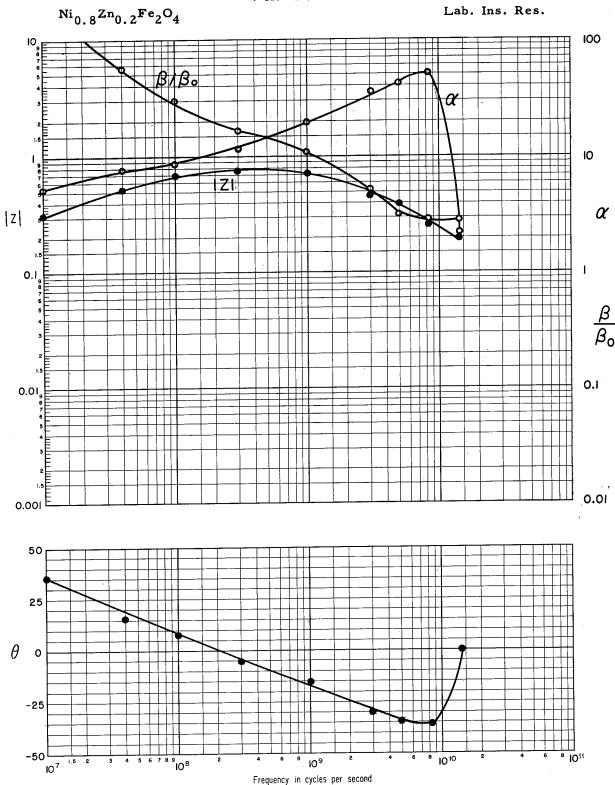




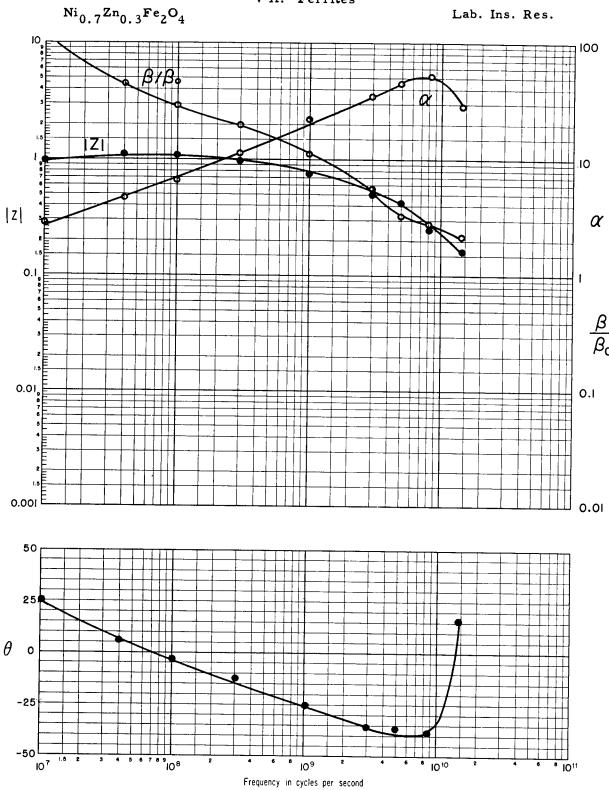


Frequency in cycles per second

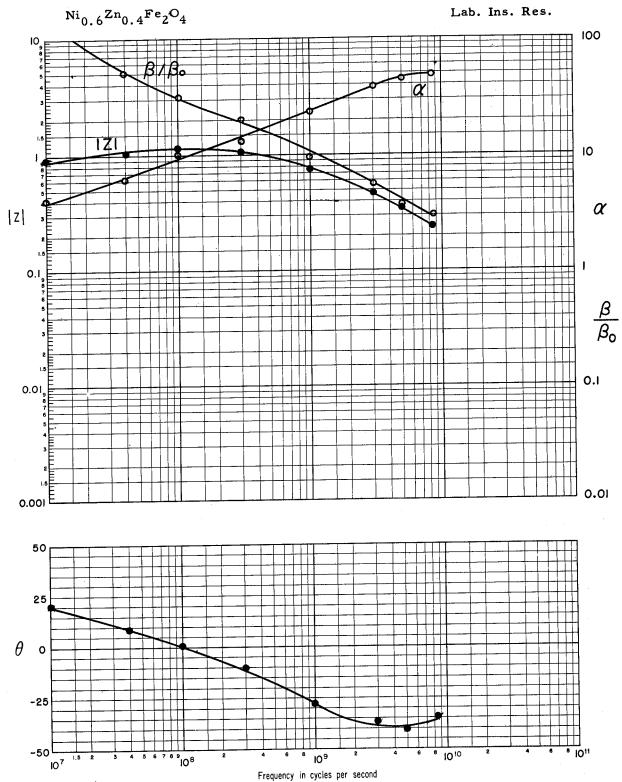
V A. Ferrites

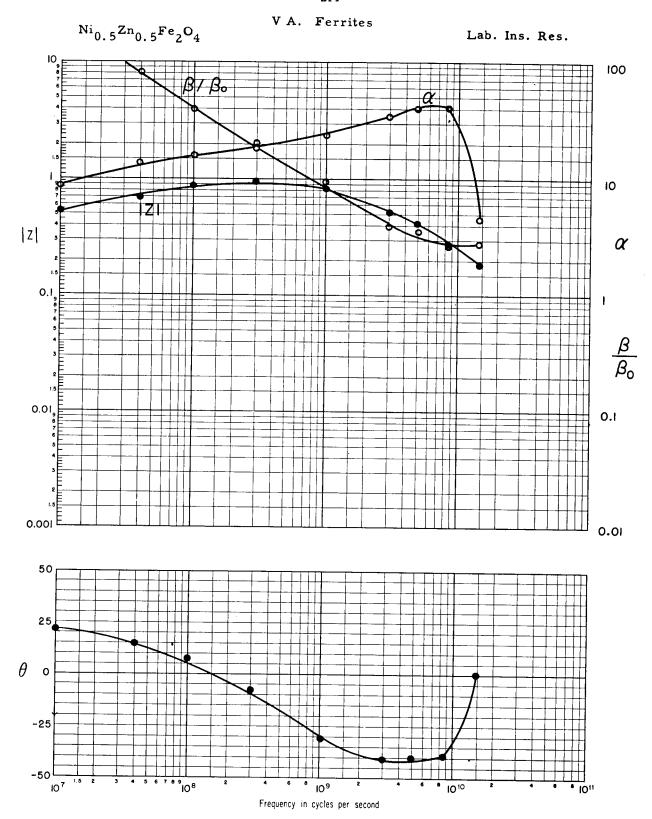


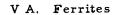
VA. Ferrites

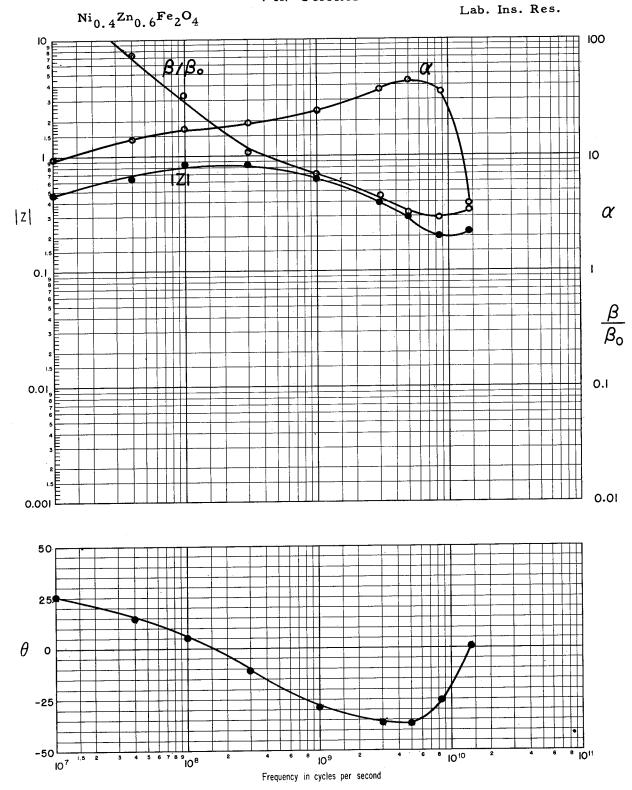


V A. Ferrites

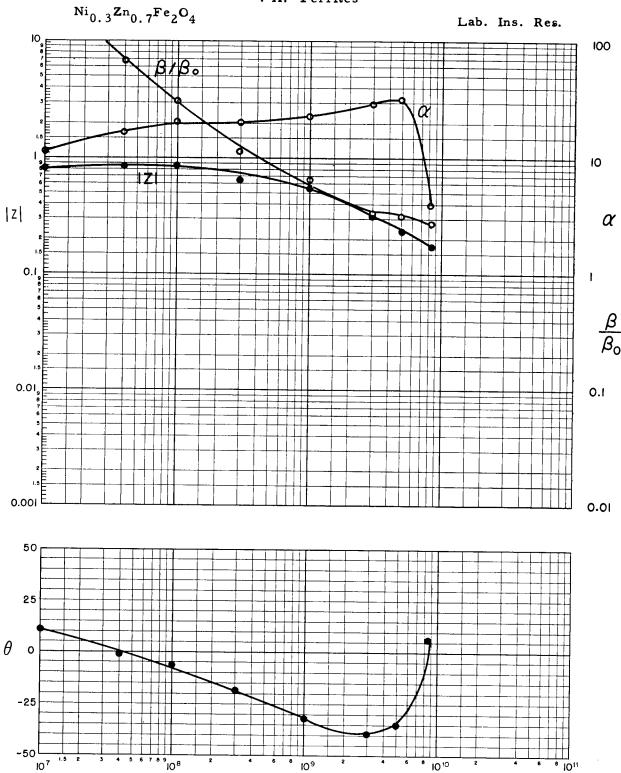






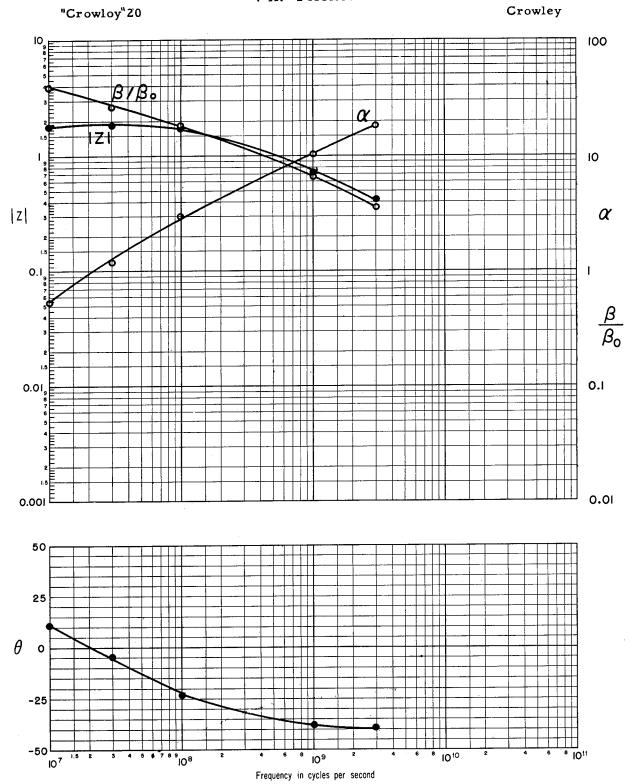


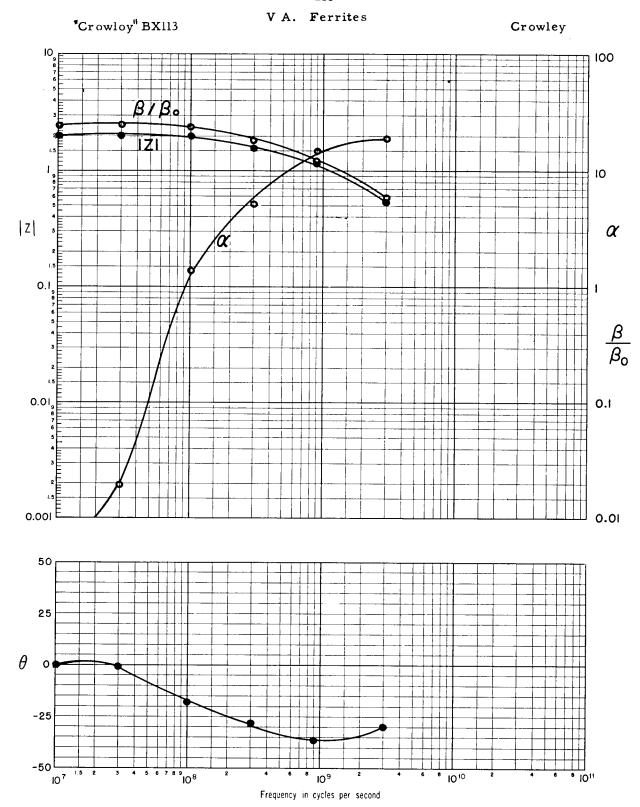
VA. Ferrites



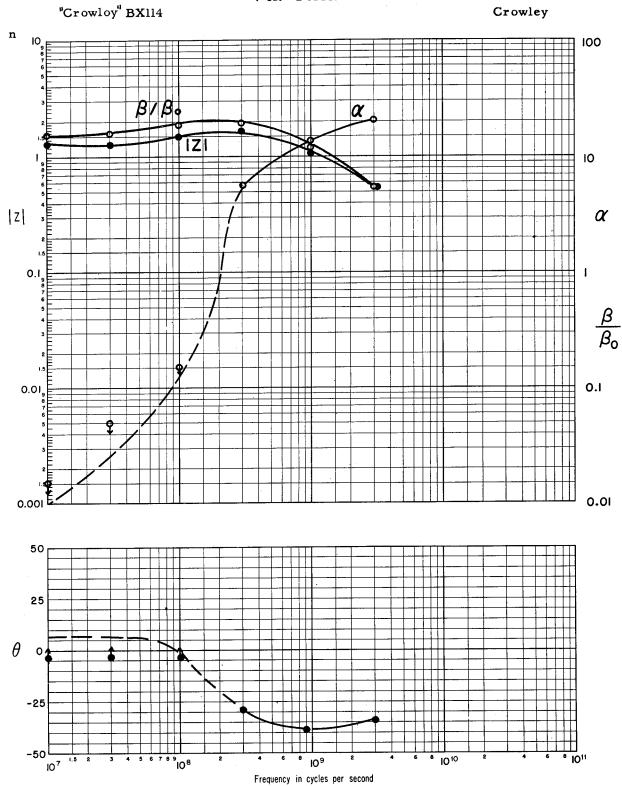
Frequency in cycles per second

V A. Ferrites

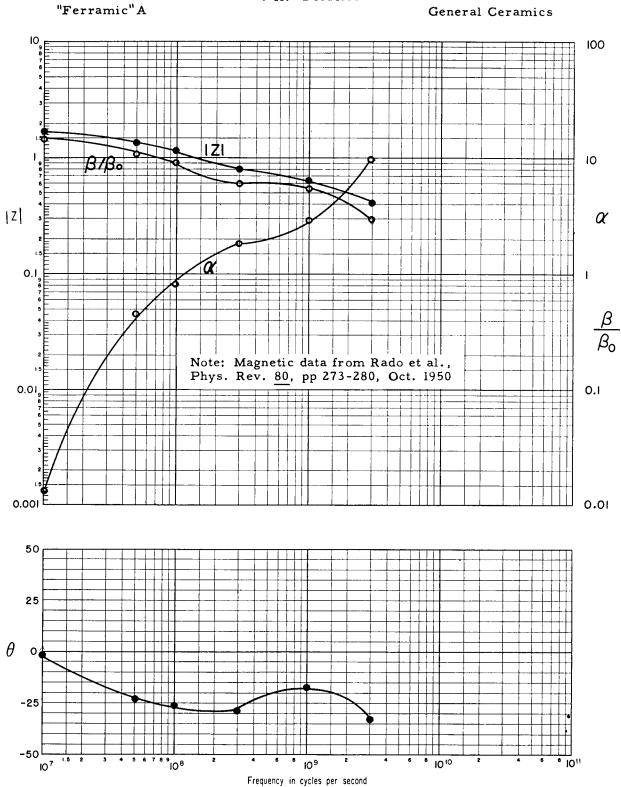


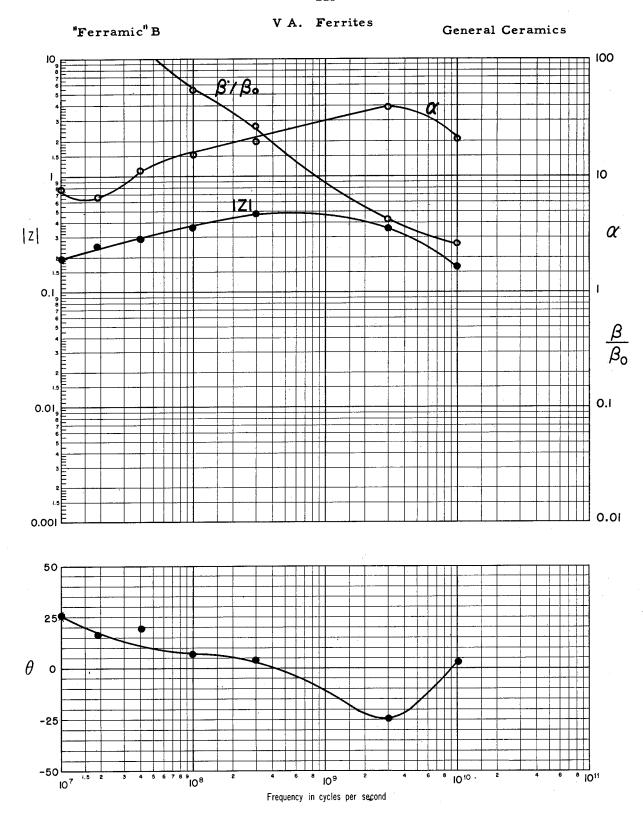


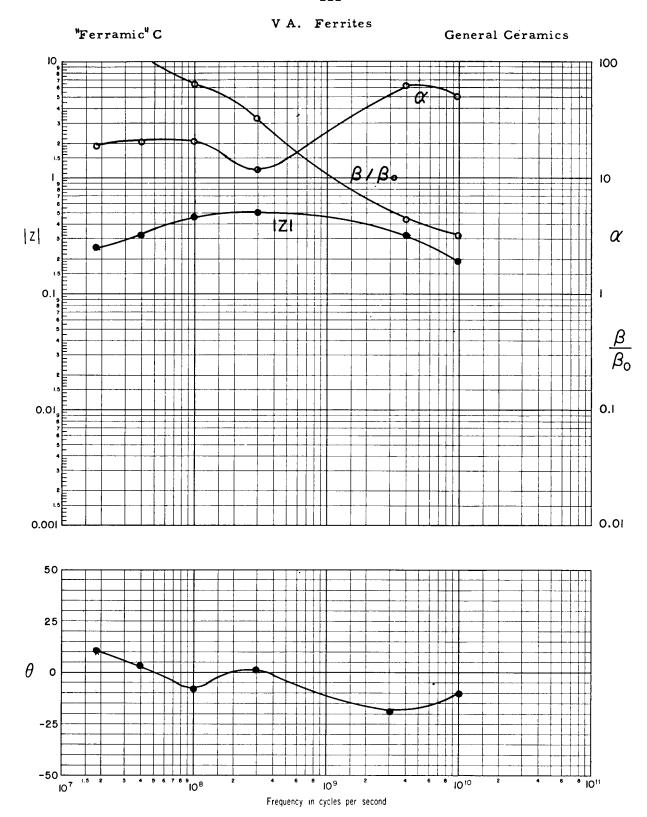
V A. Ferrites

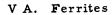


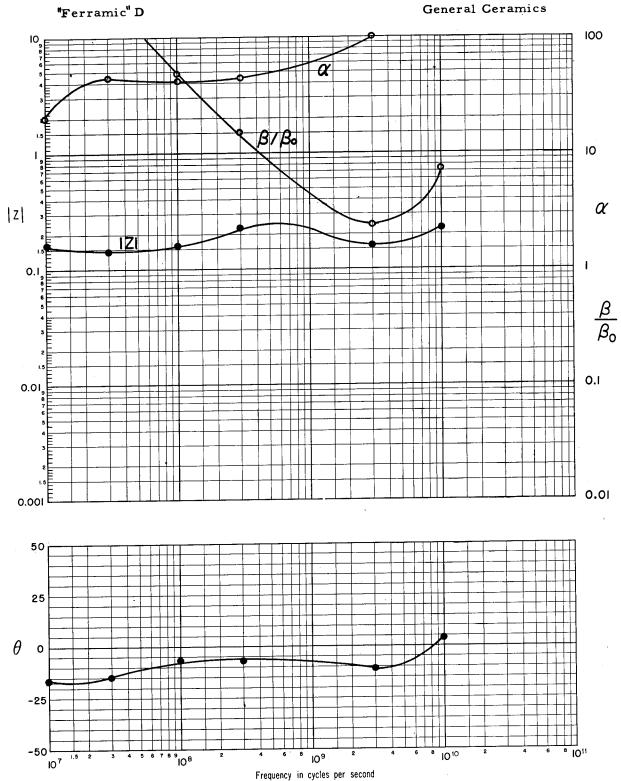
V A. Ferrites

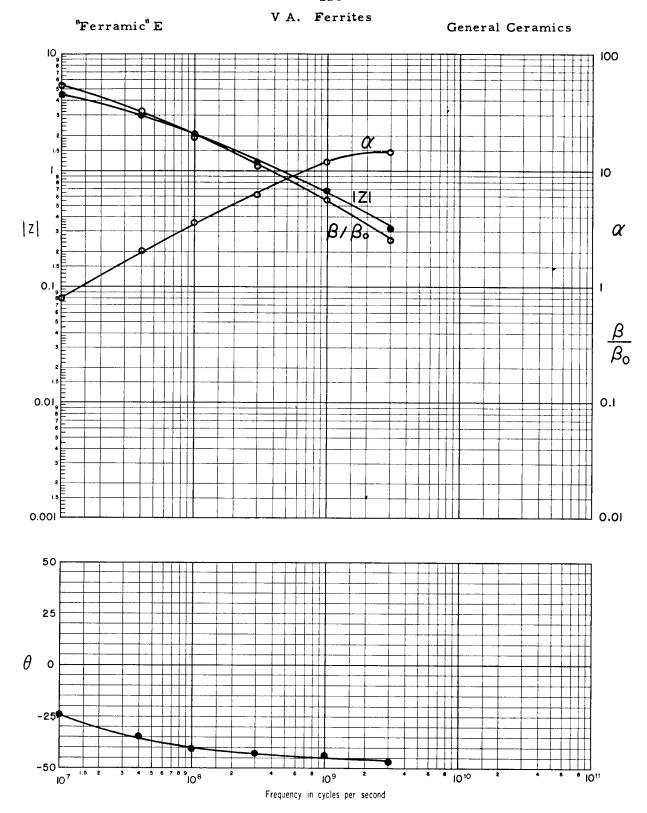


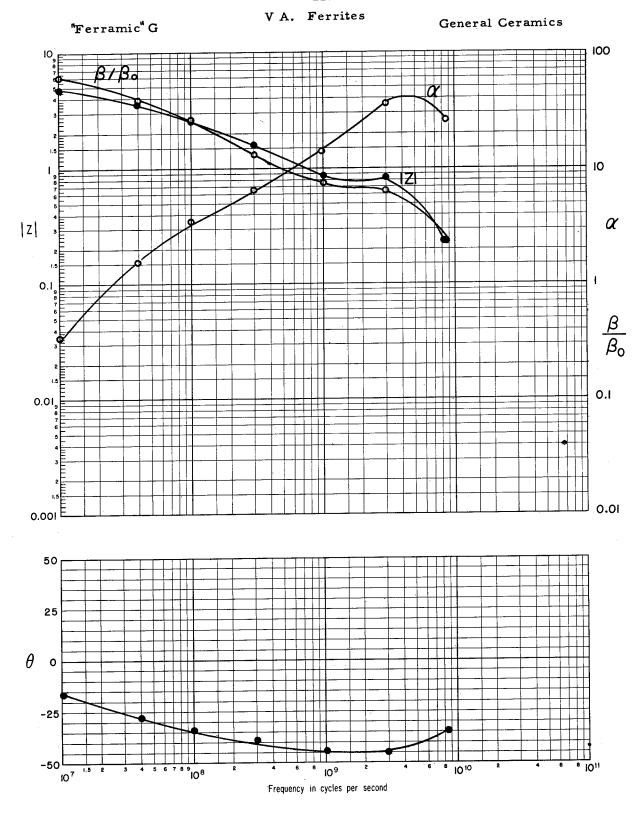




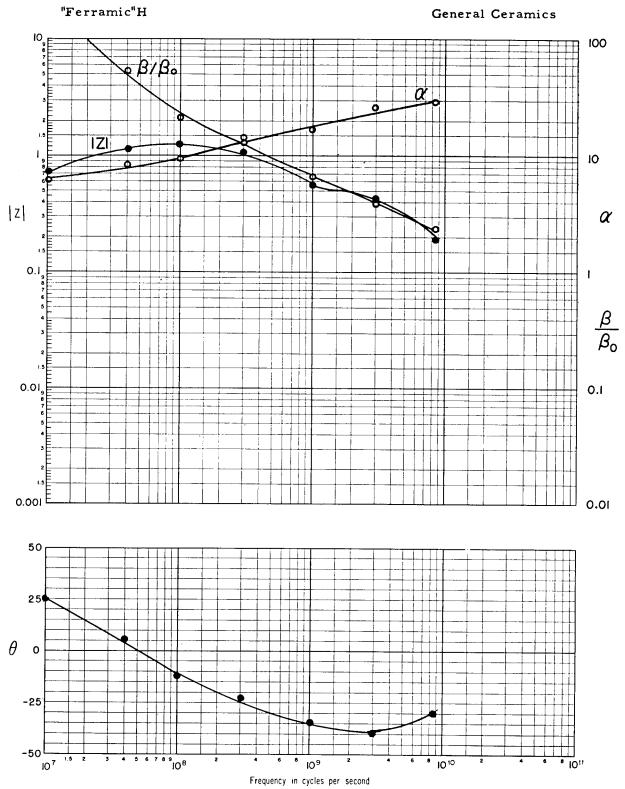


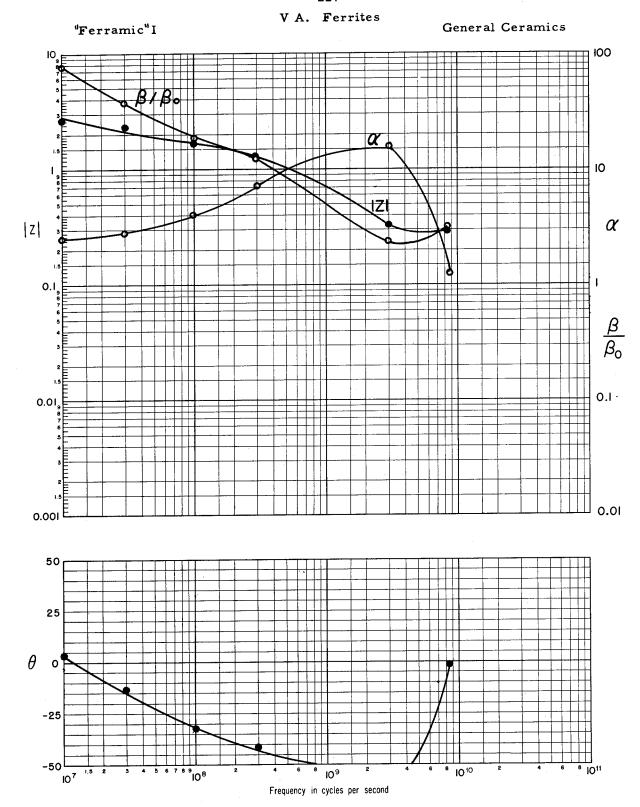




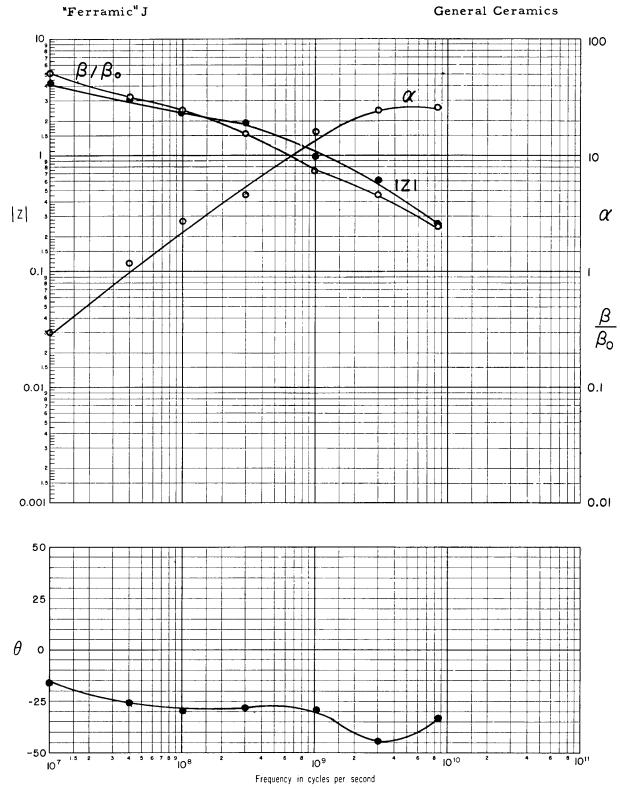


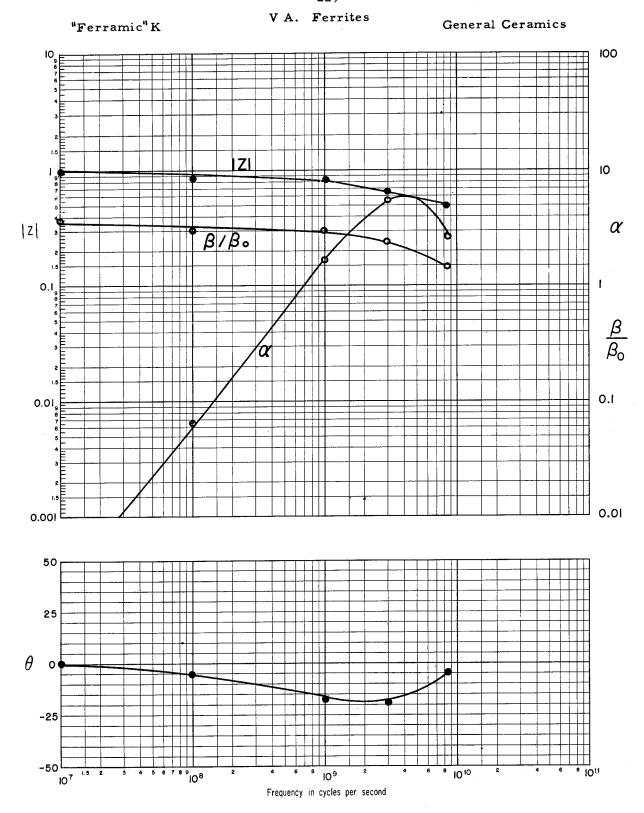
VA. Ferrites



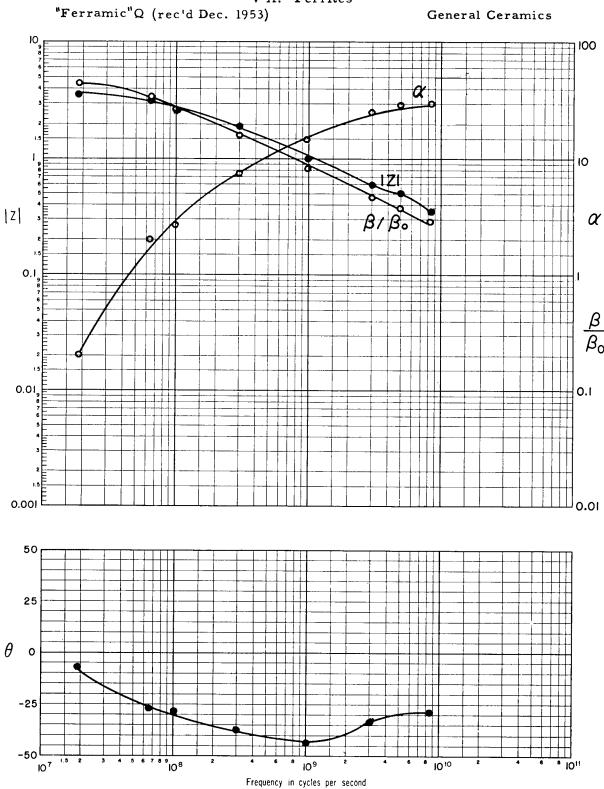


V A. Ferrites

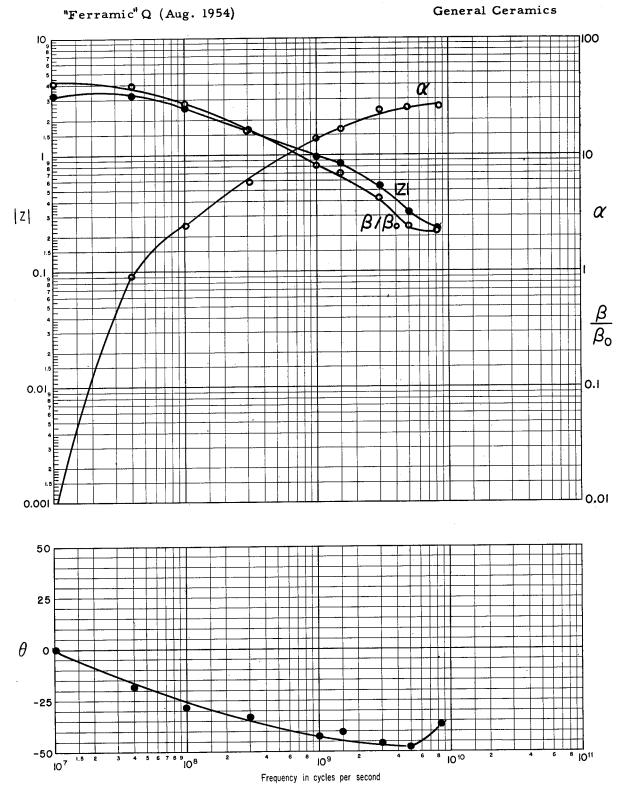


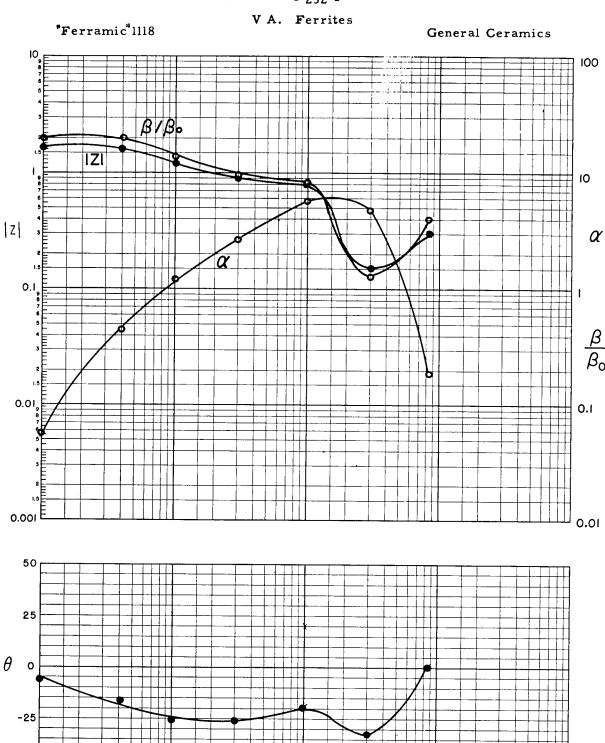


V A. Ferrites

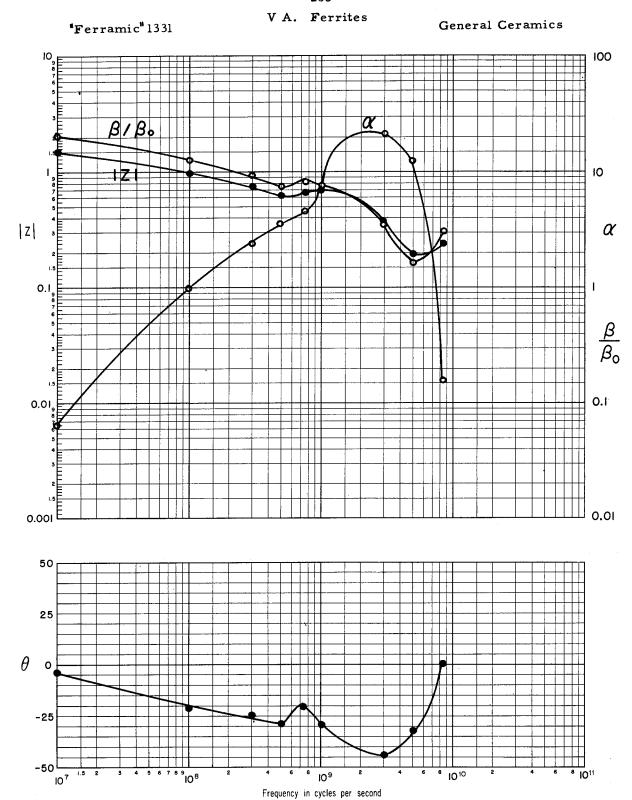


V A. Ferrites

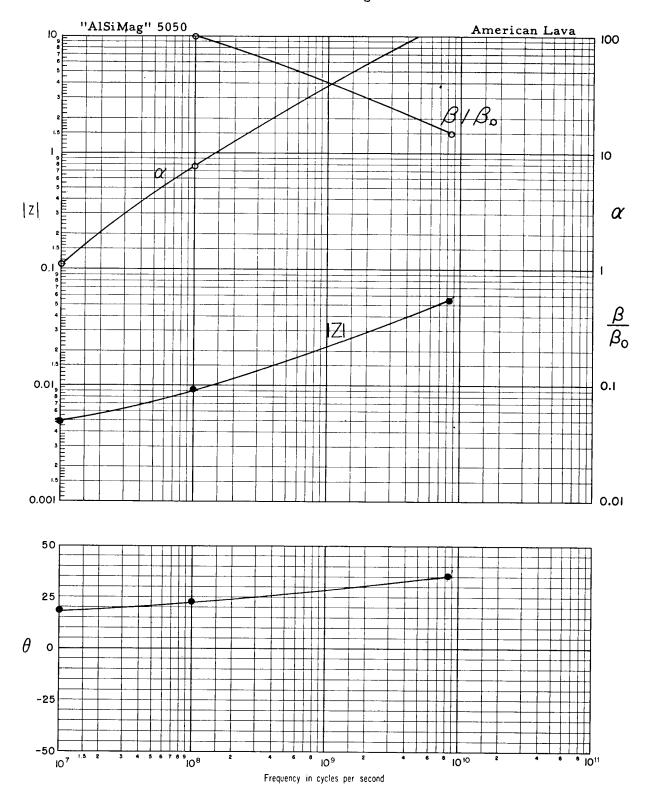




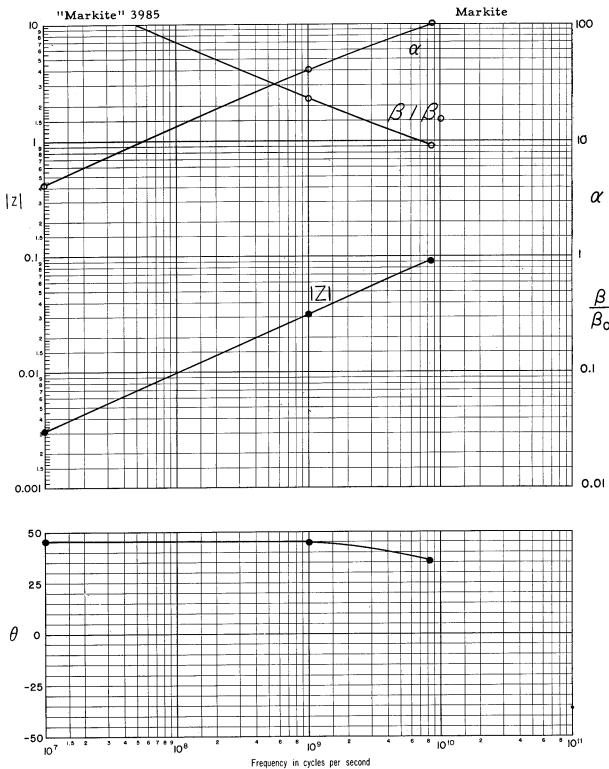
Frequency in cycles per second



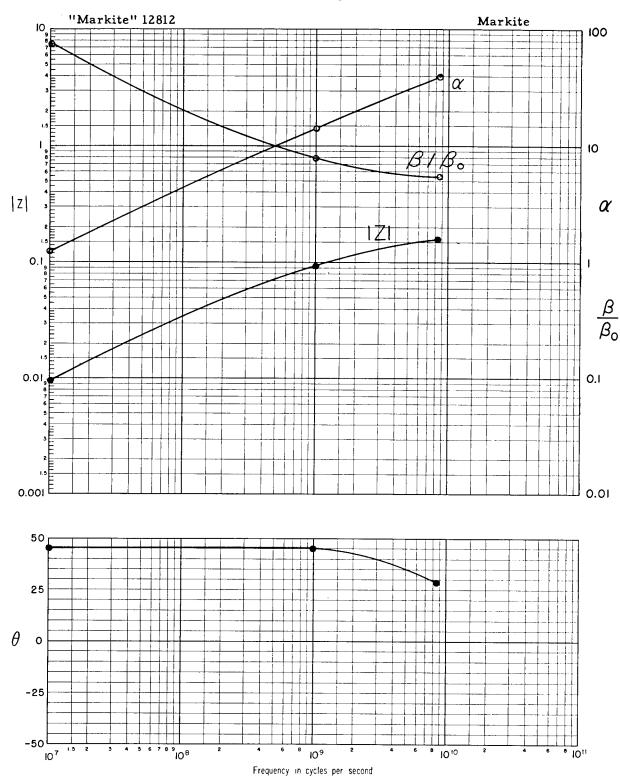
V B. Conducting Ceramics



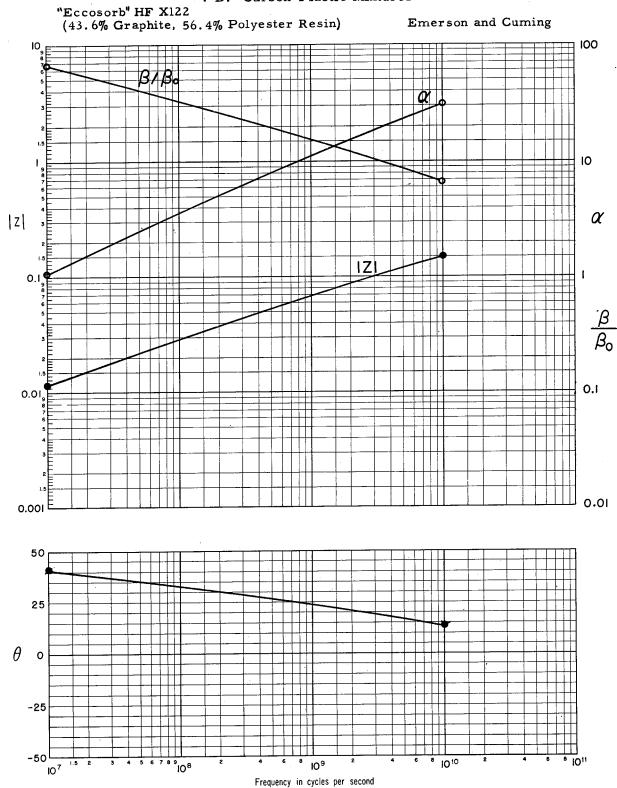
V A. Conducting Plastics

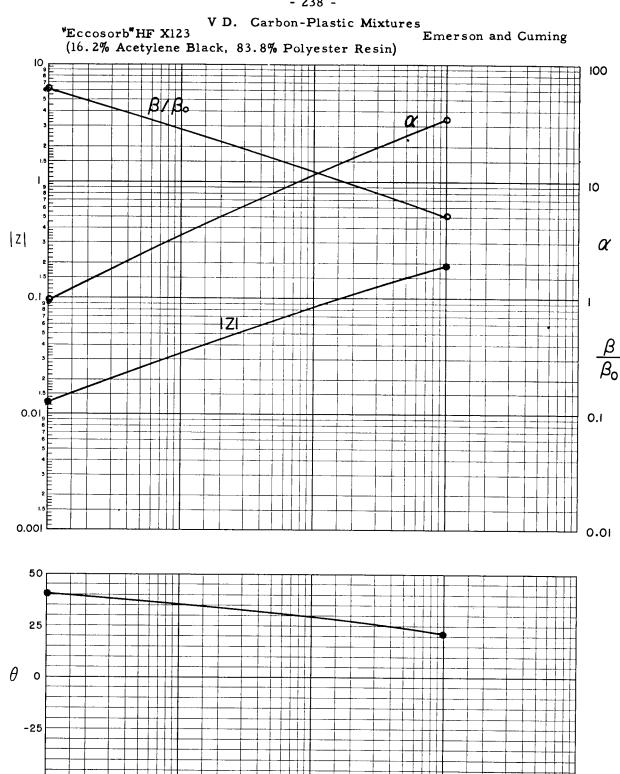


V C. Conducting Plastics



- 237 - V D. Carbon-Plastic Mixtures



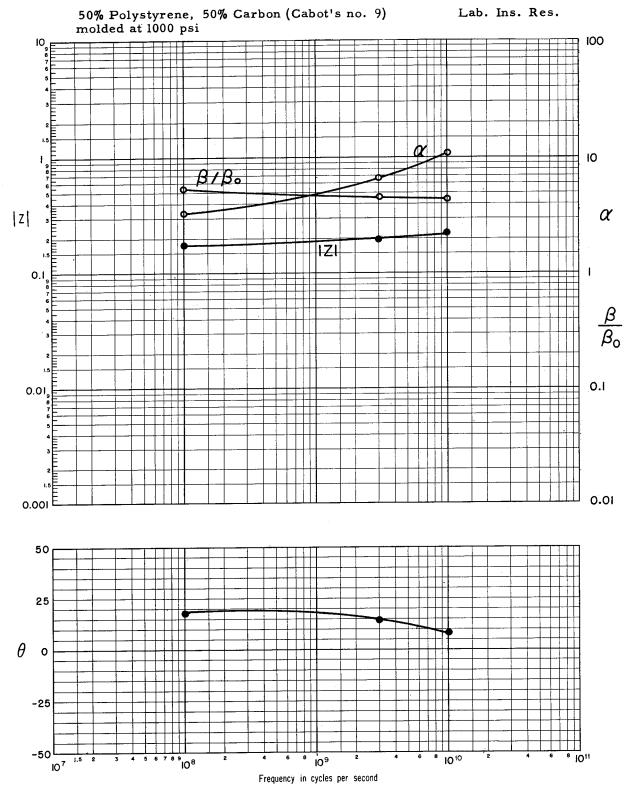


6 8 IO₉

Frequency in cycles per second

1010

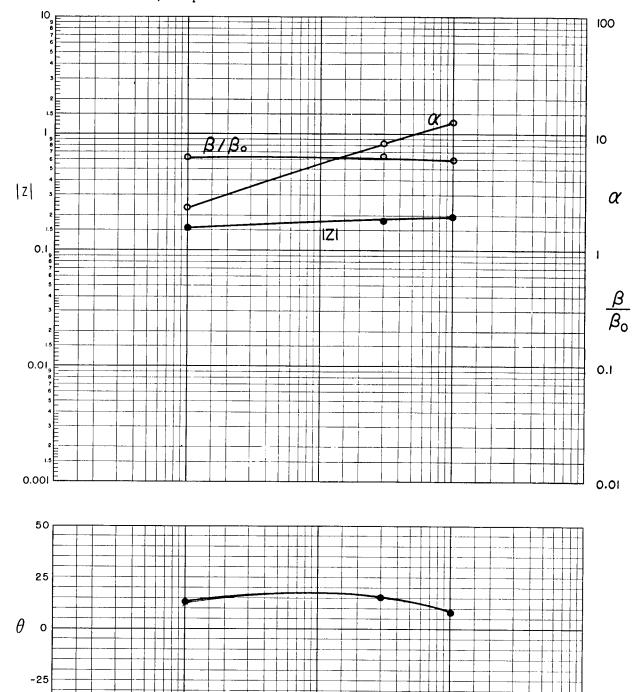
V D. Carbon-Plastic Mixtures



V D. Carbon-Plastic Mixtures

50% Polystyrene, 50% Carbon (Cabot's no. 9) molded at 10,000 psi

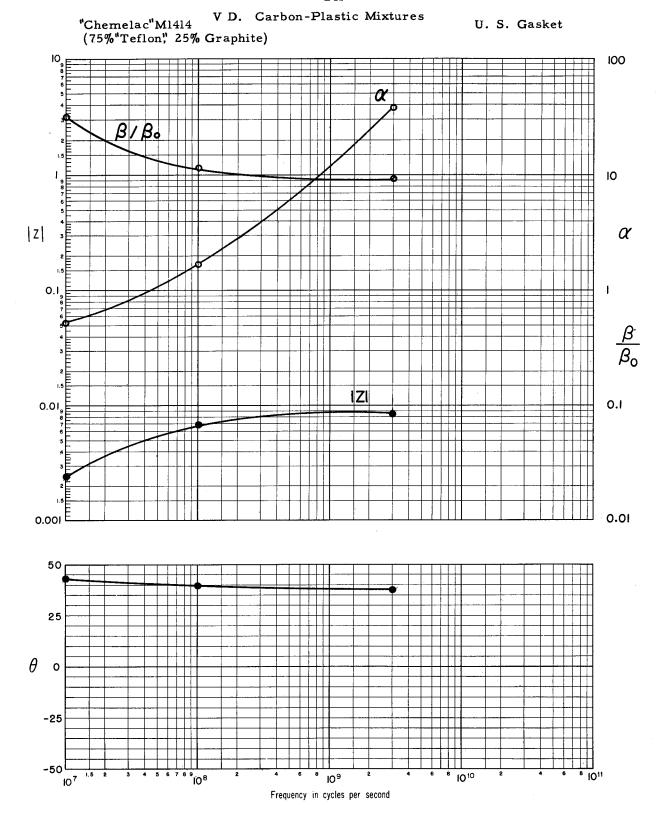
Lab. Ins. Res.



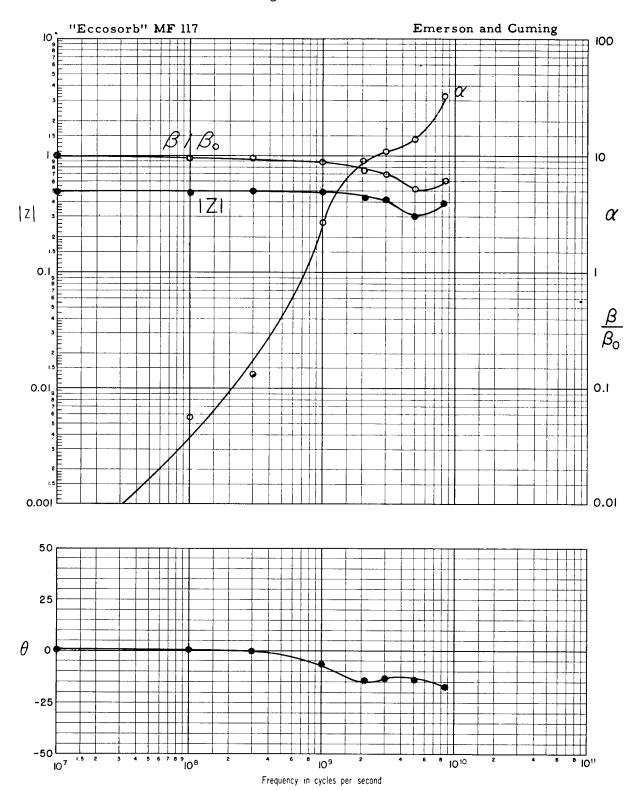
Frequency in cycles per second

6 8 1O 1O

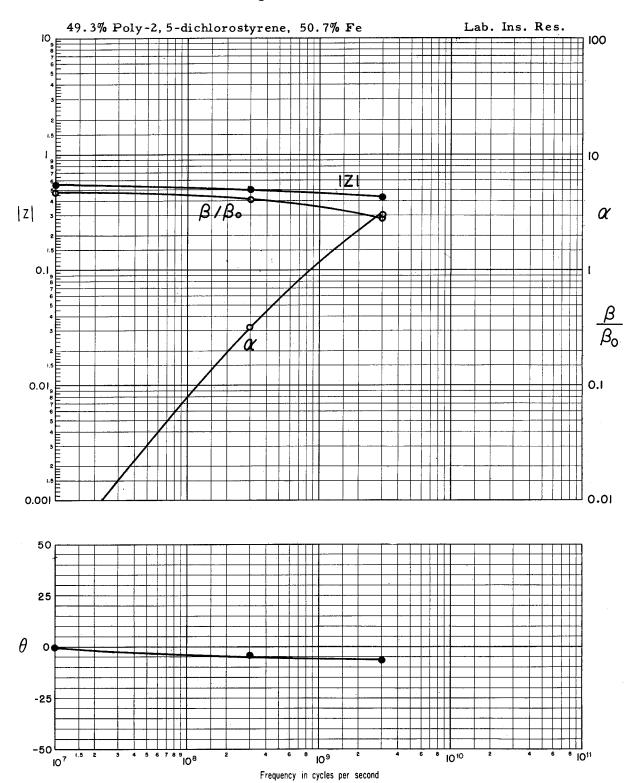
6 8 IO₉



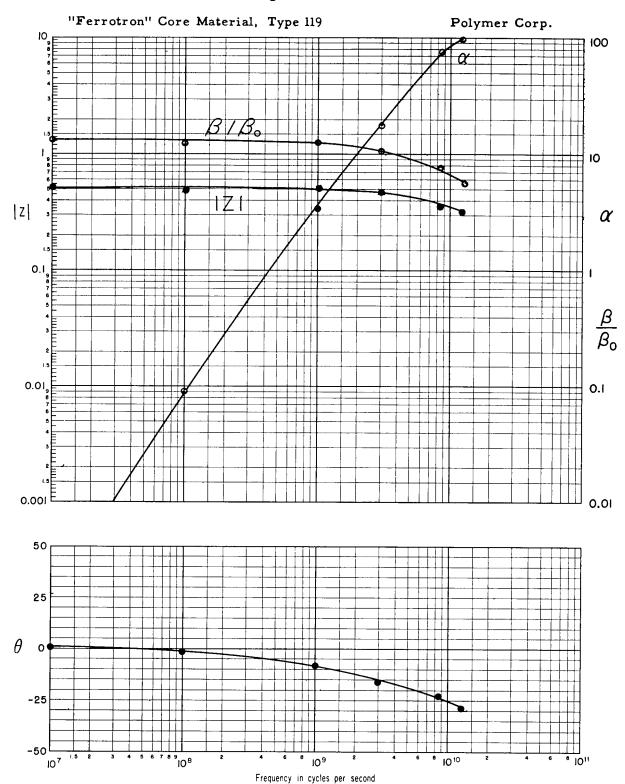
V E. Magnetic-Plastic Mixtures



V E. Magnetic-Plastic Mixtures



V E. Magnetic-Plastic Mixtures



Company Index for Vols. IV* and V

- Aircraft-Marine Products, Inc., IV-14; V-74 2102 Paxton St. Harrisburg 2, Pa.
- Air Reduction Sales Co., V-20 122 Mt. Vernon St. Dorchester, Mass.
- Allison, William M., and Co., Iv-58 162 Water St. New York, N.Y.
- Amber Mines, Inc., IV-55 353 Fifth Ave. New York, N.Y.
- American Cyanamid Co., IV-21-23, 38, 46, 112, 118-121; V-8, 106, 107 Plastics Devel. Labs. 1937 West Main St. Stamford, Conn.
- American Feldmuehle Corp., V-21, 30 11 West 42nd St. New York 36, N.Y.
- American Lava Corp., IV-3, 4, 6, 78-82, 88-93, 100; V-1, 2, 4, 5, 21, 31-39, 58-61, 75, 234 219 Kruesi Bldg. Chattanooga 5, Tenn.
- American Optical Co., IV-9
 2 Mechanic St.
 Southbridge, Mass.
- American Phenolic Corp., IV-28 1830 South 54th Ave. Chicago 50, Ill.
- American Smelting and Refining Co., IV-13
 120 Broadway
 New York 5, N.Y.
- Atlas Powder Co., V-11, 12 New Murphy Road Wilmington 99, Del.

- Bakelite Corp., IV-15, 16, 20, 27-29, 36, 48, 57, 58, 64; V-12 30 East 42nd St.

 New York 17, N.Y.
- Bell Telephone Laboratories, IV-3, 83; V-56,57 463 West St. New York, N.Y.
- Beryllium Corp., The, V-21, 52, 53 Tuckerton Rd. Reading, Pa.
- Bromund, E.A., and Co., IV-57 ll-A Warren St. New York, N.Y.
- Brush Electronics Co., IV-1,73 3405 Perkins Ave. Cleveland 14, O.
- California Research Corp., IV-65 Box 1627 Richmond, Calif.
- Candy and Co., Inc., IV-57 35th St. at Maplewood Ave. Chicago, Ill.
- Cantol Wax Co., IV-59
 211 N. Washington St.
 Bloomington, Ind.
- Carborundum Co., The, V-6,76-79 Niagara Falls, N.Y.
- Catalin Corp. of America, IV-16-18, 36, 39, 119
 Plant and Labs.
 Fords, N.J.
- Celanese Corp. of America, IV-24, 25, 114, 115; V-9, 10, 12, 90
 Plastics Div.
 290 Ferry St.
 Newark 5, N.J.

Add 301 to Vol. IV page numbers to find corresponding page in "Dielectric Materials and Applications," A.R. von Hippel, Editor, The Technology Press, Mass. Inst. Tech., and John Wiley and Sons, New York, 1954.

- Cellular Rubber Products, Inc., IV-51 1000 Norwich Rd. Willimantic, Conn.
- Central Scientific Co., IV-56 79 Amherst St. Cambridge, Mass.
- Centralab Div., Globe-Union, Inc., IV-3, 84-87
 932 E. Keefe Ave.
 Milwaukee l, Wis.
- Ciba Co., Inc., IV-21, 49, 50, 125
 Plastics Div.
 627 Greenwich St.
 New York, N.Y.
- Components and Systems Lab. See: U.S., Components and Systems Lab.
- Continental-Diamond Fibre Co., IV-18, 19, 21, 26, 27, 31, 32; V-8, 12, 14, 80-83, 88, 93, 104, 108, 114 Bridgeport, Pa.
- Coors Porcelain Co., IV-6,94-99; V-2,21,40 Ford St. Golden, Colo.
- Cornell Aeronautical Labs., IV-48,124 Cornell University Ithaca, N.Y.
- Corning Glass Works, IV-9-11, 26, 41, 42, 102, 103; V-2, 5, 6, 41, 62-71 Physical Lab. Res. and Devel. Dept. Corning, N.Y.
- Crowley, Henry I., and Co., Inc., IV-4, 7; V-217-219
 1 Central Ave.
 West Orange, N.J.
- Delaware Research and Development Corp., V-9 222 Sunset Drive, Delaire Wilmington 3, Delaware

- Dennison Mfg. Co., IV-58 45 Ford Ave. Framingham, Mass.
- Dewey and Almy Chemical Co., IV-38 Organic Chemicals Div. 62 Whittemore Ave. Cambridge 40, Mass.
- Diamonite Products Div., V-2, 3, 42-45 U.S. Ceramic Tile Co. 217 4th St. N.E. Canton 2, Ohio
- Dow Chemical Co., IV-36-42, 46, 64, 117; V-91
 Plastics Div.
 1000 Main St.
 Midland, Mich.
- Dow Corning Corp., IV-26, 27, 41, 42, 54, 55, 66, 67, 126; V-9, 20, 94, 95 592 Saginaw Rd.
 Midland, Mich.
- Du Pont, E.I. de Nemours and Co. Electrochemicals Dept., IV-33,64 Du Pont Bldg. Wilmington 98, Del.

Film Dept., V-9,13,92 Nemours Bldg. Wilmington 98, Del.

Organic Chemicals Dept., IV-53 (Elastomers Div.)
Dept. RT
Wilmington 98, Del.

Photo Products Dept., V-13,109 Wilmington 98, Del.

Pigments Dept., IV-4 Nemours Bldg. Wilmington 98, Del.

Polychemicals Dept., IV-23, 25, 27, 32, 34, 35, 58, 113; V-10, 89 Wilmington 98, Del.

Textile Fibers Dept., V-8,10,12, 14,110 Nemours Bldg. Wilmington 98, Del

- Durez Plastics, IV-17,20
 Div., Hooker Electrochemical Co.
 17 Walck Rd.
 North Tonawanda, N.Y.
- Durite Plastics, Inc.,* IV-17,19 5000 Summerdale Ave. Philadelphia, Pa.
- East Coast Aeronautics, Inc., V-ll 10 Pelham Parkway Pelham Manor 65, N.Y.
- Eastman Kodak Co., IV-15, 62 343 States St. Rochester 4, N.Y.
- Electronic Mechanics, Inc., IV-13,108
 70 Clifton Blvd.
 Clifton, N.J.
- Emerson and Cuming, V-7,8,10, 11,13-15,115,237,238,242 869 Washington St. Canton, Mass.
- Engineering Research and
 Devel. Lab.
 See: U.S., Eng. Res. and
 Devel. Lab.
- Enjay Co., Inc., IV-28, 39, 50 15 West 51st St. New York 19, N.Y.
- Esso Laboratories
 See: Enjay Co., Inc.
- Ethylene Chemical Corp., V-10 245 Broad St. Summit, N.J.
- Ferroxcube Corp. of America, V-4 500 E. Bridge St. Saugerties, N.Y.

- Filtered Rosin Products, Inc., IV-56 Baxley, Ga.
- Formica Co., The, IV-17, 20, 21, 25, 46, 47
 4614 Spring Grove Ave.
 Cincinnati 32, O.
- Frenchtown Porcelain Co., IV-6; V-3, 48, 49 99 Muirhead Ave. Trenton 9, N.J.
- General Aniline and Film Corp., IV-34,46 230 Park Ave. New York, N.Y.
- General Cable Corp., IV-52 Bayonne, N.J.
- General Ceramics Co., IV-4, 8, 83; V-3, 4, 54, 55, 159-175, 191-204, 220-233 Keasbey, N.J.
- General Electric Co., 100 Woodlawn Ave., IV-63-65 Pittsfield, Mass.

Chemical Materials Dept., IV-48 l Plastics Ave. Pittsfield, Mass.

Plastics Dept., IV-50 l Plastics Ave. Pittsfield, Mass.

1 River Rd., IV-13, 106, 107 Schenectady, N.Y.

Silicone Products Dept., IV-55, 67; V-127-129 Waterford, N.Y.

Lamp Division, IV-11, 104; V-72, 73 Nela Park Cleveland 12, O.

^{*}Now The Borden Co., Chemical Div., Dept. T-56, 350 Madison Ave., New York 17, N.Y.

- General Mills, Inc., IV-23 Central Ave. at 17th Minneapolis 13, Minn.
- Glastic Corp., The, IV-47, 49 Glenridge at Princeton Cleveland 3, O.
- Glenco Corp., IV-5, 6 200 Durham Ave. Metuchen, N.J.
- Glyco Products Co., IV-56,59 Empire State Bldg. New York, N.Y.
- Goodrich, B.F., Chemical Co., IV-29, 30
 Avon Lake Experimental Station
 P.O. Box 122
 Avon Lake, O.
- Goodyear Aircraft Corp., IV-48; V-8,9,84-87,96-101 1220 Massillon Rd. Akron 15, O.
- Goodyear Tire and Rubber Co. Plastics Dept., IV-40, 51, 52 Akron 16, O.
- Gulf Oil Corp., IV-58 2900 Gulf Bldg. Pittsburgh, Pa.
- Hardman, H.V., Co., Inc., IV-49,51
 571 Cortland St.
 Belleville 9, N.J.
- Harshaw Chemical Co., The, IV-1,2; V-1,30
 1933 East 97th St.
 Cleveland 6, O.
- Hartwell, H.N., and Sons, Inc., V-10 31 St. James Ave. Boston, Mass.
- Haveg Corp., V-17 900 Greenbank Rd. Wilmington 8, Del.

- Hercules Powder Co., Inc., IV-23; V-16 Cellulose Products Dept. Parlin, N.J.
- Hood Rubber Co., IV-22 98 Nichols Ave. Watertown 72, Mass.
- Hooker Electrochemical Co., IV-62; V-13 1940 Ward St. Niagara Falls, N.Y.
 - Plastics Div., see: Durez
- Houghton Labs., Inc., IV-50; V-15, 16, 126 4151 Russell St. Olean, N.Y.
- Hunson, C.W., V-7 P.O. Box 244 Sioux Falls, S.D.
- Irvington Varnish and Insulator Co., V-17 17 Argyle Terrace Irvington 11, N.J.
- Johns-Manville, IV-13 22 East 40th St. New York 16, N.Y.
- Kearfott Co., Inc., V-3, 46, 47 1378 Main Ave. Clifton, N.J.
- Kearney, James R., Corp., IV-52 4236 Clayton Ave. St. Louis 10, Mo.
- Kellog, M. W., Co., The, IV-31, 58, 63, 116; V-10, 18, 19, 102, 103, 130, 131
 Foot of Danforth Ave.
 Jersey City 3, N.J.
- Knox Porcelain Corp., IV-6,100 2700 Mynders St. Knoxville 11, Tenn.

- Kuhne-Libby Co., IV-57
 54 Front St.
 New York, 4, N.Y.
- Laminated Plastics, Inc. See: Glastic Corp.
- Linde Air Products Co., The, IV-1, 2, 72, 77; V-1, 26-28 East Park Dr. and Woodward Ave. Tonawanda, N.Y.
- Lovell Chemical Co., IV-57, 58; V-16 Watertown 72, Mass.
- Lucoflex Plastic Fabricating, Inc., IV-30
 242 Village St.
 Medway, Mass.
- Mallinckrodt Chemical Works, IV-44, 45, 61, 62 Second and Mallinckrodt Sts. St. Louis 7, Mo.
- Marbon, Chemical Div. of Borg-Warner Corp., IV-38 1926 West 10th Ave. Gary, Ind.
- Marco Chemicals, Inc.*, IV-47 Sewaren, N.J.
- Markite Co., V-22, 235, 236 155 Waverly Place New York 14, N.Y.
- Mass. Inst. of Technology
 Cryogenic Eng. Lab., V-18
 Rm 41-202
 77 Mass. Ave.
 Cambridge 39, Mass.
 - Lab. for Insulation Research, IV-1, 2, 5, 11, 12, 26, 37, 41-46, 62, 64, 105; V-1, 133-139, 142-158, 177-180, 183-190, 206-216, 239, 240, 243

Rm 4-244, 77 Mass. Ave. Cambridge 39, Mass.

- Lincoln Laboratory, V-140, 141, 176, 181, 182
 Rm 20C-105
 77 Mass. Ave.
 Cambridge 39, Mass.
- Mathieson Chemical Corp., See: Olin Mathieson
- Mica Insulator Co., IV-21 801 Broadway Schenectady, N.Y.
- Minnesota Mining and Mfg. Co., IV-63; V-16,17,22
 900 Fauquier Ave.
 St. Paul 6, Minn.
- Mitchell-Rand Insulation Co., Inc., IV-57-59
 51 Murray St.
 New York, N.Y.
- Monsanto Chemical Co.
 Plastics Division, IV-15,18,20,
 22,24,30,36,37,41-45,63,64
 100 Monsanto Ave.
 Springfield 2, Mass.
- Rubber Chemical Sales, Dept. of
 Organic Chemicals Div., V-ll
 920 Brown St.
 Akron ll, Ohio
 Organic Chemicals Div., V-l9
 800 N. 12th Blvd.
 St. Louis l, Mo.
- Morse, Herbert B., and Co., V-16,17 354 Washington St. Wellesley, Mass.
- Mycalex Corp. of America, IV-13; V-7, 79 Dept. 120-A, P.O. Box 311 Clifton, N.J.
- Narmco Resins and Coatings Co., V-8 Victoria and Placentia Costa Mesa, Calif.
- National Research Corp., V-3
 70 Memorial Drive
 Cambridge, Mass.

^{*} Now Celanese Corp. of America, 290 Ferry Street, Newark 5, N.J.

- Naugatuck Chemical, Div. of U.S. Rubber Co., IV-47,53 132 Elm St. Naugatuck, Conn.
- Norton Co., IV-1, 6; V-3, 29, 49 50 New Bond St. Worcester 6, Mass.
- Olin Mathieson Chemical Corp., IV-41; V-20 Mathieson Bldg. Baltimore 3, Md.
- Owens-Corning Fiberglas Corp., IV-11, 16, 22, 47, 48; V-6, 8, 13 Research and Development Labs. Newark, O.
- Pennsylvania Industrial
 Chemical Corp., IV-39,50
 Clairton, Pa.
 (Products distributed by
 Standard Chemical Co.,
 Akron 8, O.)
- Phillips Petroleum Co., V-19 Chemical Products Dept. Bartlesville, Okla.
- Phillips Chemical Co., V-10
 Plastics Sales Div.
 Bartlesville, Okla.
- Pittsburgh Corning Corp., IV-11; V-13,19 Dept. TR, One Gateway Center Pittsburgh 22, Pa.
- Plaskon Div., IV-22, 23, 47, 49, 123; V-112, 113 Allied Chemical and Dye Corp., Dept. R-2 Toledo, O.
- Plastic Metals, Div. of National U.S. Radiator Corp., IV-43, 44 123 Bridge St. Johnstown, Pa.

- Plax Corp., IV-35 P.O. Box 1019 Hartford 1, Conn.
- Polaroid Corp., IV-35, 37, 40; V-11 741 Main St. Cambridge, Mass.
- Polymer Corp. of Pennsylvania, V-17,18,205,244 2140 Fairmount Ave. Reading, Pa.
- Procter and Gamble Co., IV-60 Ivorydale Cincinnati 1, O.
- Raybestos-Manhattan, Inc., V-8, 9
 Asbestos Textile and Packing Div.
 Manheim, Pa.
- Raytheon Mfg. Co., V-3 90 Willow St. Waltham, Mass.
- Resinous Products Div.
 See: ROHM and HAAS Co.
- Rex Corp., IV-40; V-11,105 Hayward Rd. West Acton, Mass.
- Rezolin, Inc., IV-19
 5736 West 96th St.
 Los Angeles 45, Calif.
- Robertson, H.H., Co., IV-48,123; V-12,19 2400 Farmers Bank Bldg. Pittsburgh 22, Pa.
- Rogers Paper Mfg. Co., IV-60 Manchester, Conn.
- Rohm and Haas Co., IV-30, 34, 48, 62, 122; V-12, 111
 712 Locust St.
 Philadelphia 5, Pa.
- Rubber Reserve Corp., IV-51, 52 Washington 1, D.C.
- Rutgers University
 School of Ceramics, V-4
 New Brunswick, N.J.

- St. Regis Paper Co., IV-17, 22
 Panelyte Div.
 Enterprise Ave.
 Trenton, N.J.
- Sauereisen Cements Co., V-7 3389 Sharpsbury Station Pittsburgh 15, Pa.
- Sharples Chemicals, Div., Penna.
 Salt Mfg. Co., IV-63
 Widner Bldg.
 Philadelphia 9, Pa.
- Shawinigan Products Corp., IV-34 Empire State Bldg. New York 1, N.Y.
- Shell Chemical Corp., IV-50; V-16, 116-125 Resins and Plastics Dept. 50 West 50th St. New York 20, N.Y.
- Shell Devel. Co., IV-46-48 4560 Horton St. Emeryville 8, Calif.
- Shell Oil Co., IV-56,66
 Special Products Dept.
 50 West 50th St.
 New York 20, N.Y.
- Socony Mobil Oil Co., Inc.,
 IV-57,58
 Formerly Socony-Vacuum
 Oil Co., Inc.
 26 Broadway
 New York, N.Y.
- Southern Alkali Corp., IV-48 Barberton, O.
- Sperry Gyroscope Co., V-18 Lake Success Great Neck, N.Y.
- Sponge Rubber Products Co:, IV-19, 31, 52 Shelton, Conn.
- Sprague Electric Co., IV-39 149 Marshall St. North Adams, Mass.
- Spruce Pine Mica Co., V-7 Greene Bldg. Spruce Pine, N.C.

- Stanco Distributors, Inc., IV-65,66 Chemical Products Dept. See: Enjay Co., Inc.
- Standard Oil Co. of N.J., IV-58
 15 W 51st St.
 New York, N.Y.
- Standard Oil Devel. Co. See: Enjay Co., Inc.
- Sterling Varnish Co., The, V-18 1954 Ohio River Blvd. Haysville Boro. Sewickley P.O., Pa.
- Stupakoff Ceramic and Mfg. Co., IV-6,101; V-3,4,50,51
 Division of the Carborundum Co. Hillview Ave.
 Latrobe, Pa.
- Syncor Products Co., V-6 22 Eastern Ave. Malden, Mass.
- Taylor Fibre Co., IV-18, 27, 111 Norristown, Pa.
- Tennessee Eastman Corp., IV-24 Kingsport, Tenn.
- Tennessee Marble, Inc., IV-13 Knoxville, Tenn.
- Thiokol Chemical Corp., IV-54
 780 North Clinton Ave.
 Trenton 7, N.J.
- Titanium Alloy Mfg. Div., IV-4,5, 42,43
 National Lead Co.
 Hyde Park Blvd.
 Niagara Falls, N.Y.
- Union Carbide and Carbon Corp., V-18 Silicones Div., Dept. EE 30 E. 42nd St. New York 17, N.Y.
- U.S. Ceramic Tile
 See: Diamonite Products Div.

- U.S. Gasket Co., IV-32, 33; 608 North 10th St. Camden, N.J.
- United States (Government)

Components and Systems
Lab., IV-9,101
Air Materiel Command
Wright-Patterson Air
Force Base
Dayton, O.

Engineering Research and Devel. Lab., IV-2,74-76 Fort Belvoir, Va.

National Bureau of Standards, IV-40 Washington, D.C.

War Department, IV-15 Picatinny Arsenal Dover, N.J.

- U.S. Industrial Chemicals Co., IV-62 99 Park Ave. New York 16, N.Y.
- U.S. Polymeric Chemicals, Inc.,V-9Canal and Ludlum Sts.Stamford, Conn.
- U.S. Rubber Co., IV-31, 40, 52, 53, 56
 General Labs.
 Passaic, N.J.

- U.S. Stoneware Co., The,V-21, 515300 East Talmadge Ave.Akron, O.
- Victor Chemical Works, IV-48 155 North Wacker Drive Chicago 6, Ill.
- War Dept., Picatinny Arsenal See: U.S. War Dept. Picatinny Arsenal
- Weber, Hermann, and Co., IV-51 76 Beaver St. New York 5, N.Y.
- Western Gold and Platinum Works, V-4, 52 Belmont, Calif.
- Westinghouse Electric Corp., Research Labs., IV-18,19,22 East Pittsburgh, Pa.
- Zinsser, Wm., and Co., IV-55, 56 513 West 58th St. New York II, N.Y.
- Zophar Mills, Inc., IV-59 112-130 26th St. Brooklyn 32, N.Y.

Materials Index for Volumes IV^* and V

"Acrawax" C, IV-56

Acrylate resins, IV-34, 35; V-10

Acrylonitrile-butadiene copolymer, IV-53

AFC Alumina, V-21

Air seal, IV-52

"Alathon," IV-27,70

Alcohols, IV-62

"Alite" AP-212 and AP-216, V-21

"Alite" Ap-312, V-21, 51

Alkyd resins, IV-47-49, 123, 124; V-112, 113

Allyl resins, IV-47, 48

Allymer CR-39, CR-39 + glass, IV-48

"AlSiMag" A-35, IV-3, 80

"AlSiMag" A-196, IV-3, 78, 79

"AlSiMag" 211, IV-3

"AlSiMag" 288, IV-3, 81

"AlSiMag" 243, IV-3, 82

"AlSiMag" 393, IV-3

"AlSiMag" 475, V-5, 59-61

"AlSiMag" 491, IV-6,100

"AlSiMag" 491 (blue), V-1, 32, 33

"AlSiMag" 505, IV-82

"AlSiMag" 513 (pink), V-1, 34, 35

"AlSiMag" 544, V-21, 31

"AlSiMag" 548, V-21, 31

"AlSiMag" 576, V-2, 36, 37

"AlSiMag" 577, V-4, 58

"AlSi Mag" 602, V-21, 75

"AlSiMag" 614, V-2

"AlSi Mag" 652, V-21, 38, 39

"AlSiMag" 5050, V-234

Aluminas, IV-6, 96-99; V-1, 2, 3, 4, 21, 23, 3-52

Alumina Mullite, V-3

Aluminum oxide, IV-3, 6, 72, 96-100; V-1, 2, 3, 4, 26, 27, 28

Aluminum silicate, V-6

"Alvar" 11/90, IV-34

Amber, IV-55

Amer. Cyanamid 405 resin, V-8

Amer. Cyanamid, see "Laminac,"
"Melmac," "Beetle"

Ammonium dihydrogen phosphate,

"Amplifilm," IV-14; V-74

Aniline-formaldehyde resins, IV-21

"Apiezon" Wax "W", IV-56

"Araldite" Adhesive, Type I, IV-50 (natural and silver)

"Araldite" Casting Resin, Type B, IV-49,125

"Araldite" Casting Resin G, IV-49

"Araldite" E-134, IV-49

"Aroclor" 1221, 1232, 1242, 1248, 1254, IV-63

"Aroclor" 1260, 1262, 5442, IV-64

"Aroclor" 1268, 4465, 5460, IV-15

Asbestos, IV-13

Asbestos filled plastics, IV-16; V-8, 9, 84, 85, 96, 97

Asphalts and Cements, IV-56

"Atlac" 382, V-11,12

^{*}Add 301 to Volume IV page numbers to find corresponding page in "Dielectric Materials and Applications," A.R. von Hippel, Editor, The Technology Press, Mass. Inst. Tech., and John Wiley and Sons, New York, 1954.

- "Bakelite" BM-120, IV-15, 16, 69
- "Bakelite" BM-250, BT-48-306, BM-16981, and BM-16981 powder, IV-16
- "Bakelite" BM-262, BM-1895, IV-20,69
- "Bakelite" BRS-16631 + glass, IV-48
- "Bakelite" BV-17085 + glass, IV-16
- "Bakelite" PLLA-5005, V-12
- "Bakelite" polystyrenes, IV-36
- "Bakelite" polyvinyl chlorideacetate, see "Vinylites"
- Balata, precipitated, IV-51
- Barium-strontium titanate, IV-5, 6
- Barium titanate, IV-5; V-1
- Barium titanate and plastic mixtures, IV-43
- "Bayol," "Bayol"-16, IV-66
- "Bayol"-D, "Bayol"-F, IV-65
- Beeswax, white, yellow, IV-57
- "Beetle" resin, IV-23
- Bell Labs. F-66, IV-3, 83; V-56,57
- Bentonite, IV-14; V-74
- Benzenes and diphenyls, chlorinated, IV-63
- Benzenes, chloro-, IV-64
- Benzoguanamine-formaldehyde resin, IV-23
- Beryllium oxide, IV-6; V-21, 24, 52, 53
- Biphenyls, chlorinated, IV-15, 63,64
- Biphenyl, diisopropyl and monoisopropyl, V-19
- Bitumen, natural, IV-56

- "Boltaron" 6200-10, V-10
- Boron nitride, V-6, 76, 77
- Boron nitride alloy, V-6,79
- Buna S (GR-S) and compounds, IV-52
- Bureau of Standards Casting Resin IV-40
- Butadiene-acrylonitrile copolymer, IV-53
- Butadiene, chloro-, IV-53,62
- Butadiene-styrene copolymer, IV-38,52
- "Butvar," Low OH and 55/98, IV-34
- n-Butyl alcohol, IV-62
- Butyl rubbers, IV-52
- Butyraldehyde, IV-62
- Cable Oil 5314 and PL101270, IV-65
- Calcium fluoride, V-1, 10
- Calcium titanate, IV-5
- Carbon, diamond, V-1
- Carbon and plastic mixtures, IV-32, 41; V-239, 240
- Carbon tetrachloride, IV-62
- Carbonyl iron and plastic mixtures, V-15
- "Catalin" 200, 500, and 700 base, IV-16,17
- "Catalin" 8012, IV-39, 119
- "Catalin" EK 2784, IV-39
- Celanese MR-31C, MR-33C, MX-186 and MX-218, V-12
- Cellulose Acetate LL-1, IV-23
- Cellulose acetate + plasticizer, IV-24
- Cellulose acetates, IV-23, 24, V-9
- Cellulose derivatives, IV-23-25; V-9, 90, 91, 92

Cellulose nitrate and camphor, IV-25

Cellulose propionate, IV-25, 114; V 9, 90

Cellulose triacetate ("CTA"), V-9,92

Cements and asphalts, IV-56

Cenco "Sealstix," IV-56

"Ceram" 61-1, V-5,65

"Ceram" 61-2, V-5, 66

"Ceram" 61-3, V-5, 67

"Ceram" 61-4, V-6, 68

"Ceram" 61-5, V-6,69

Ceramic NPOT 96, IV-4,88,89

Ceramic N750T96, IV-4,90,91

Ceramic N1400T110, IV-4, 92, 93

Ceramic T106, IV-4

Ceramics, IV-3, 78; V-30, 136, 206

Cerese Wax AA and brown, IV-57

Ceresin, white and yellow, IV-57

Cesium bromide, V-1

Cesium iodide, V-1

Cetylacetamide, IV-56

"Chemelac" M1405, M1406, M1407, M1411, and M1412, IV-32

"Chemelac" M1414, IV-32, V-241

"Chemelac" M1418-2, M1418-5, M1422, and M1423, IV-33

"Chemelac" B-3, IV-56

Chlorinated benzenes and biphenyls, IV-15, 63, 64

β-chloroethyl-2,5-dichlorobenzene, IV-64

Chlorostyrenes, ortho and para, copolymer, IV-42

Chlorotrifluoroethylene dimer, trimer, V-18

Chlorotrifluoroethylene tetramer, pentamer, hexamer, V-19

"Cibanite, " IV-21

Cobalt ferrite (M.I.T. samples), V-136,177,206

"Conolon" 506, V-8

Coors AB-2, IV-6, 98, 99

Coors AI-200, IV-6, 96, 97; V-2, 21, 40

Coors AL-100, V-2, 40

"Copolene" B, IV-28

"Corfoam" 114, IV-19

Corning aluminas, JB-123 and WD-131, V-2

Corning aluminas JD-40, JD-82, JB-183, V-2, 41

Corning Glass Nos. 0010, 0014, 0080, 0090, 0100, 0120, 1770, IV-9

Corning Glass No. 1990, IV-9,102

Corning Glass Nos. 1991, 3320, 7040, 7050, IV-9

Corning Glass Nos. 7052, 7055, 7060, IV-10

Corning Glass No. 7070, IV-10, 102, V-62, 63

Corning Glass Nos. 7230, 7570, 7720, 7740, 7750, IV-10

Corning Glass No. 7900, IV-10, V-67

Corning Glass No. 7910, V-5

Corning Glass No. 7911, IV-10, 103

Corning Glass Nos. 8460, 8830, IV-10

Corning Glass No. 8603, V-5

Corning Glass Nos. 8871, 9010, Lab. No. 189CS, IV-11

Crepe, pale and compounds, IV-51

Cresylic-acid formaldehyde resins, IV-18, 19, 68, 70

"Crolite" No. 29, IV-4

"Cronar," V-13,109
"Crowloy" 20, IV-7; V-217
"Crowloy" 70, IV-7
"Crowloy" BX113, IV-7; V-218
"Crowloy" BX114, IV-7; V-219
Crystals, inorganic, IV-1, 2, 72-77; V-1, 26-30, 133-135
Crystals, organic, IV-15
"Dacron"-filled plastics, V-8,10, 12,14,110
"Darex" No. 3, 43E, X-34, X-43, IV-38
"DeKhotinsky" Cement, IV-56
"Diala" Oil, IV-66
Diallyl phenyl phosphonate resin, IV-48
"Diamonite" B-890, V-2,42
"Diamonite" P-3142, V-2, 43
"Diamonite" P-3459, V-2,44
"Diamonite" P-3530-40, V-3,45
Diatomaceous-earth ceramic, IV-6,101
Dibutyl sebacate, IV-62
Dichloronaphthalenes, mixture of the 1, 2-, 1, 4- and 1, 5-iso- mers, IV-58
Dichloropentanes Nos. 14 and 40, IV-63
2,5-Dichlorostyrene, IV-64
Diisopropyl biphenyl, V-19
"Dilectene" 100, IV-21
"Dilecto" (hot punching) XXX-P-26, IV-19; V-80, 81
"Dilecto" ("Mecoboard"), IV-18; V-82,83
"Dilecto" GB 112S, IV-27
"Dilecto" GB-112T, IV-31, 32; V-104

"Dilecto" GB-116E and GB-126E, V-14

```
"Dilecto" GB-181E, V-14, 114
"Dilecto" GB-261S, IV-26; V-93
"Dilecto" GM-1, V-8,88
"Dilecto" GM-PE, V-12, 108
Dioctyl sebacate, IV-62
Diphenyl, see Biphenyl
Dow-Corning:
    Fluids, 200, IV-66
            500, IV-66
            550, IV-67
            710, IV-67
    Grease, No. 4, IV-67
            high vacuum, V-20
    Molding cmpds, XM-3, IV-26
             301, V-9,94
    Resins, 996, IV-26
            2101, IV-26
            2103, IV-26, 27
            2105, V-9,94
            2106, V-9, 95-101
    Silastics, 120, IV-54
              125, IV-54
              150, IV-54
              152, IV-54
              160, IV-54
              167, IV-54
              180, IV-54
              181, IV-54, 126
              250, IV-54,126
              6181, X4342, IV-55
              6167, IV-55, 126
              XF6620, IV-55; V-20
              X6734, IV-55
              7181, IV-55
Dow C-244, IV-36
Dow Experimental Plastic Q-166,
    Q-166 + Fiberglass, Q-200.5,
```

Dow Experimental Plastic Q-247.1,

Dow Experimental Plastic Q-344,

IV-39

IV-36

IV-40

- Dow Experimental Plastic Q-406, IV-37, 117
- Dow Experimental Plastic Q-409, IV-42
- Dow Experimental Plastic Q-475.5, IV-40
- Dow Experimental Plastic Q-764.6 and Q-767.2, IV-37
- Dow Experimental Plastic Q-817.1, IV-37,117
- "Durez" 1601, natural, IV-17
- "Durez" 11863, IV-20
- "Durite" No. 500, IV-17
- "Durite" No. 221X, IV-19
- "Ecco" L65, V-11
- "Eccofoam" GL, V-8
- "Eccofoam" HiK (1000°F), V-7
- "Eccofoam" HiK (500°F), V-14, 115
- "Eccofoam" PS, V-10
- "Eccosorb" HFX122, V-13, 237
- "Eccosorb" HFX123, V-13, 238
- "Eccosorb" HF155, HF680, HF853, HF1000, HF2050, V-13
- "Eccosorb" MF110, MF112, MF114 and MF116, V-15
- "Eccosorb" MF117, V-15,242
- E Resin, IV-50
- Elastomers, IV-51-55; V-127-129
- "Elvacet" 42A-900, IV-33
- "Elvanol" 51A-05, 50A-42, 70A-05, 72A-05, 72A-51, IV-33
- "Ensolite" M22240, M22239, 3036, IV-31
- "Epon" Resin RN-48, IV-50
- "Epon" 828, V-16, 116-125
- "Epon" X-131, V-16

- Epoxy resins, IV-49, 50, 125; V-14-16, 114, 126
- Epoxy laminates with:
 - "Dacron, " V-14
 - "Fiberglas," IV-50; V-14, 16, 22, 114, 124, 125
 - "Nylon, " V-14
 - "Orlon, " V-14
- "Estawax," IV-57
- "Ethocel" LT5, IV-25, 115; V-91
- Ethyl alcohol, IV-62
- Ethyl cellulose, IV-25, 115; V-91
- Ethylene Glycol, IV-62
- Ethylpolychlorobenzene, IV-64
- "Ferramic" A, V-159, 191, 220
- "Ferramic" B, V-160, 192, 221
- "Ferramic" C, V-161, 193, 222
- "Ferramic" D, V-162,194,223
- "Ferramic" E, V-163, 195, 224
- "Ferramic" G, V-164, 196, 225
- "Ferramic" H, V-165,197,226
- "Ferramic" H-1, V-4, 166, 198
- "Ferramic" I, V-167, 227
- "Ferramic" J, V-168, 199, 228
- "Ferramic" K, V-169, 229
- "Ferramic" N, V-200
- "Ferramic" Q (rec'd Dec. 1953), V-170, 230
- "Ferramic" Q (rec'd Aug. 1954), V-171, 201, 231
- "Ferramic" MF874, V-172, 202
- "Ferramic" 1118, V-173, 232
- "Ferramic" 1326B, V-174, 203
- "Ferramic" 1331, V-175, 204, 233
- "Ferramic" 3310 (experimental), V-176

Ferrites, IV-7; V-4, 54, 133-204, 206-233

"Ferrotron" 119, V-17, 205, 244

"Ferrotron" 308, 309, V-18

"Ferroxcube" 105, V-4

"Fiberfrax" Board, V-6,78

"Fiberglas" laminates, IV-16, 18, 22, 25-27, 31, 32, 47-50, 68; V-8-11, 13, 14, 16, 22, 86-88, 93-95, 98-101, 104

"Fiberglas" BK-174, laminated, IV-16

"Fibestos" 2050TVA C-1686, IV-24

"Foamglas, " IV-ll

Formaldehyde resins, aniline, IV-21

Formaldehyde resins, benzoguanamine, IV-23

Formaldehyde resins, cresol, IV-18,19,68,70

Formaldehyde resins, melamine, IV-21, 22, 112

Formaldehyde resins, phenol, IV-15-19,109-111

Formaldehyde resins, phenolaniline, IV-20

Formaldehyde resins, urea, IV-23

"Formica" FF-41 (sheet, rod stock), IV-21,68

"Formica" FF-55, IV-21,69

"Formica" G7, G6, IV-25

"Formica" Grade MF-66, IV-20,68

"Formica" XX, LE, IV-17,68

"Formica" YN-25, IV-17

"Formica" Z65, IV-46

"Formica" Z80, IV-47

"Formvar," Type E, IV-34

"Forticel" No. 28102, IV-25; V-90

"Forticel" JLB-(H), V-9

"Forticel" JMB-(M), V-9

"Fortiflex" A, V-10

"Fotoceram" (843 GU) and (843 GZ), V-5

"Fotoform" B(843 GU), B(843 GZ), C(843 GU), C(843 GZ), E(843 GU), and E(843 GZ), V-5

"Fractol" A, IV-66

Frenchtown 4462, IV-6; V-3, 48

Frenchtown 6096, V-3, 48

Frenchtown 7873, V-3, 49

Furfuraldehyde resin, phenol, IV-19

"Gafite" cast polymer, IV-34

Gasoline, aviation, 100 and 91 octane, IV-65

General Ceramics ADH-211, V-3

General Ceramics BM3054, V-4,55

General Ceramics 7294, IV-4, V-55

General Ceramics "Ferramics", see "Ferramics"

Geon 2046, 80365, 80384, IV-29

Gilsonite, IV-56

Glasses, IV-9-12,101-105; V-5,6,62-73

Glass, alkali-silica, IV-12,105

Glass, alkaline lead silicate, IV-ll

Glass, aluminum borosilicate, IV-10

Glass, aluminum zinc-phosphate, IV-9

Glass and mica, IV-13, 69, 106-108

Glass and plastic mixtures, IV-41, 42

Glass, barium borosilicate, IV-10

Glass, borosilicate, IV-9,101

Glass, "E", IV-11

Glass, iron-sealing, IV-9,102

Glass Lamicoid No. 6038, IV-21, 70

Glass, lead-barium, IV-9

Glass, lime-alumina-silicate, IV-9

Glass, low alkali, potash-lithiaborosilicate, IV-10, 102; V-62, 63

Glass, phosphate 2043x, 2279x, IV-9

Glass, potash-lead-silicate, IV-9

Glass, potash-soda-bariumsilicate, IV-9

Glass, silica, IV-10, 103; V-64

Glass, soda-borosilicate, IV-9,10

Glass, soda-lead-borosilicate, IV-10

Glass, soda-lime-silicate, IV-9, ll

Glass, soda-potash-borosilicate, IV-9

Glass, soda-potash-lead-silicate, IV-9

Glass, soda-potash-lithia-borosilicate, IV-10

Glass, soda-silica, IV-ll

"Glastic" GF, MM, MP and A-2, IV-48

"Glastic" S and MF, IV-47

"Glyptol" No. 1201 (red), IV-48

Grease, hi-vacuum, V-20

Grease, "KEL-F" No. 40, IV-63

GR-I (butyl rubber) and compound, IV-52

GR-S (Buna S) and compounds, IV-52

Gutta-percha, IV-51

"Halowax" No. 1001, IV-57

"Halowax" No. 11-314, IV-58

"Halowax" Oil 1000, IV-64

Heptacosafluorotributyl, IV-63

Heptane, IV-62

Hexachlorobutadiene, IV-62

Hexamethylene-adipamide polymer, IV-23, 113

Hexane, V-19

Hooker 32A, V-13

"Hycar" OR "Cell-tite," IV-52

Hydrocarbon polymer, crosslinked, IV-50

Hydrocarbons, petroleum, IV-65,66

12-Hydroxystearin, IV-58

"Hysol" 6000 and 6020, IV-50

"Hysol" 6000 HD, V-15,126

"Hysol" 6030, IV-50,70

"Hysol" 6030-B, V-15

"Hysol" XL-6060, V-15

"Hysol" XE-6080, V-16

"Hy-tuf" Laminate Grade GF181, IV-50

Ice, IV-1

Ignition Sealing Compound No. 4, IV-67

Iron and plastic mixtures, IV-43, 44; V-243

Iron-manganese oxide and plastic mixtures, IV-45

Irvington tape, V-17

Isobutylene-isoprene copolymer, IV-52

Jet fuel JP-1 and JP-3, IV-65

Jet fuel JP-4, V-19

Kearfott alumina, V-3, 46, 47

"Kel-F," IV-31

"Kel-F" Alkanes 464, 695, V-18

"Kel-F" Alkanes 8126, 10157, 12188, V-19

"Kel-F" Grade 300 and 300-P25, IV-31, 116

"Kel-F" X200, V-10, 102, 103

"Kel-F" Grease No. 40, IV-63

"Kel-F" Oil, Grade No.1 and No.3, IV-63

"Kel-F" Oil, Grade No. 10, IV-63; V 130,131

"Kel-F" Wax No. 150, IV-58

Kerosene, IV-65

"Koroseal" 5CS-243, IV-30

"Kralastic" BE, BM, D, EBMU, F, IV-53

KRS-5, IV-2,76

KRS-6, IV-2, 75

"Laminac" 4115, IV-46,120

"Laminac" 4-205, IV-46,121

"Laminac" 4232, V-106,107

"Laminac" PDL7-627 and PDL7-650, IV-46,120

Laminates and impregnated batts, see filter or resin:

Asbestos-filled plastics
"Dacron"-filled plastics
Epoxy laminates
"Fiberglas" laminates
Melimine GMG
"Nylon"-filled plastics
"Orlon"-filled plastics
Ppper laminates
phenolic Resin plus fillers
Polyester resin plus fillers
Polystyrene plus fillers
Silicone resin plus fillers

"Laminate" BD-44 and BK 164, IV-47, 48

Lava, V-21, 75

Leather, sole, IV-60

Liquids, aliphatic, IV-62,63; V-18,19.130,131

Liquids, aromatic, IV-63, 64; V-19

Liquids, inorganic, IV-61; V-18

Liquids, organic, IV-62-67; V-18, 19, 20

Liquids, petroleum, IV-65,66

Liquids, silicone, IV-66, 67; V-20

Lithium fluoride, IV-l

Lithium-nickel ferrite (M.I.T. samples), V-137,178

"Loalin, " IV-36

"Lucite" HC-202, V-10

"Lucite" HM-119 and HM-140, IV-34, 70

"Lucite," sintered, IV-34

"Lucoflex," IV-30

"Lumarith" XFA-H4 and 22361, IV-24, 25, 70

"Lustrex" loaded glass mat, IV-41

Magnesium ferrite (M.I.T. samples), V-138,179,207

Magnesium-manganese ferrite (M.I.T. samples), V-139, 140,180,181,208

Magnesium-manganese-zinc ferrite (M.I.T. samples), V-141,182

Magnesium manganite, V-4, 54

Magnesium oxide, IV-l; V-29

Magnesium silicate, IV-3, 78-82

Magnesium titanate, IV-4

Magnesium titanate and plastic mixture, IV-43

Magnetite and plastic mixtures, IV-44, 45

Manganese-magnesium ferrite (M.I.T. samples), V-139,140, 180,181,208

Manganese-magnesium-zinc ferrite (M.I.T. samples), V-141,182

Marble S-303, IV-13

"Marbon" S, Buna S Hardboard, IV-52

"Marbon" S (Code 7206), S-1 (Code 7254), 8000 and 9200, IV-38

Marco Resin "MR"-21C, "MR"-23C and "MR"-25C, IV-47

"Marcol, " IV-65

"Markite" 3985, V-20,235

"Markite" 12812, V-20, 236

"Marlex" 50, V-10

Mathieson Plastic CY-8 and CQ-10DM, IV-41

Meat, IV-60

"Mecoboard, " IV-18; V-82-83

Melamine-formaldehyde resins, IV-21, 22, 112; V-8, 88

Melamine GMG, IV-21, 70

"Melamac" 7278 + "E" glass, IV-22

"Melmac" Molding Comp. 1500, 1502, IV-22, 112

"Melmac" Resin 592, IV-21

"Melmac" Type 1077 (Ivory WB 48), IV-21

Methacrylate resins, IV-34,35

"Methocel," IV-25

Methyl alcohol, IV-62

Methyl cellulose, IV-25

Methylstyrene-styrene copolymer, IV-39

Mica and glass, IV-13, 69, 106-108; V-7, 79

Mica, Canadian, IV-13

Mica-filled plastics, IV-16, 17, 18, 20

"Micaramic," V-7

Mica, ruby, IV-13

"Micarta" No. 254, IV-18

"Micarta" No. 259, IV-22, 68

"Micarta" No. 299, IV-19, 68

"Micarta" No. 496, IV-18, 68, 70

"Millimar," IV-56

Minn. Mining EC-612, V-17

"Missileon," V-17

Monoisopropyl biphenyl, V-19

Monsanto OS-45, OS-59 and OS-82, V-19

Morse 200, V-16

Morse 280, 300, 400, 6060-C and 6062, V-17

Muscovite, IV-13

"Mycalex" K10, IV-13

"Mycalex" 400, IV-13, 69

"Mycalex" 2821, IV-13, 106, 107

"Mykroy" Grade 8 and 38, IV-13, 108

"Mylar" A, V-13

Naphthalene, IV-15

Naphthalene, chloro-, IV-64

Naugatuck Laminating Resin MP and MT, IV-47

Neoprene GN and compound, IV-53

Nickel ferrite (M.I.T. samples), V-133-135,142,143,183,209

Nickel-lithium ferrite (M.I.T. samples), V-137,178

Nickel-zinc ferrite (M.I.T. samples), V-144-157, 184-190, 210-216

Nitrobenzene, IV-64

Nitrogen, gas, V-20

Nitrogen, liquid, V-18

Nitrous oxide gas, V-20

Norton 7X, V-3,49

Norton 17Z, V-3

"Nylon" 66 and 610, IV-23

"Nylon" FM 10, 001, IV-23, 113;

"Nylon"-filled plastics, IV-17; V-8, 12, 14, 82, 83

Oil, HB-40, IV-63

Oils, petroleum, IV-65,66

"Opalwax, " IV-58

"Orlon"-filled plastics, V-8, 10, 12, 14

Owens-Corning CR-262, 57M, EA63, EA73, X600, V-6

"Ozokerite, "IV-58

Panelyte Grade 140 and 776, IV-17, 22

Paper, Kraft, V-18

Paper laminates, IV-17-19, 21-23, 46; V-80

Paper, Royalgrey, IV-60

Paraffin, natural, IV-58

Paraffin Wax 132° ASTM and 135° AMP, IV-58

"Paraplex" P13, IV-48, 122

"Paraplex" P43, IV-48; V-12, 111

"Parowax," IV-58

"Pelron" 9420, 9422, 9423 and 9424, V-11

"Penton, " V-16

Perfluorodihexyl ether, IV-63

"Permafil," 3256, IV-50

"Permo" potting Compound No. 49 and No. 51, IV-49, 51

Petroleum oils, IV-65,66

Phenol-aniline-formaldehyde resins, IV-20

Phenol-formaldehyde resins, IV-15-19, 109-111

Phenol-furfuraldehyde resin, IV-19

Phenolics, IV-15-20, 109-111; V-8, 80-87

Phenolic, Expanded, IV-19

Phenilic paper laminate JH-1410, IV-18

Phenolic resin with asbestos, V-8,84,85

Phenolic resin with "Dacron," V-8

Phenolic resin with "Fiberglas," V-8,86,87

Phenolic resin with "Nylon," V-8

Phenolic resin with "Orlon," V-8

Phenolic spheres, V-12

"Phoresin," IV-48

"Piccolastic" D-125, IV-39

"Piccopale," Resin, IV-50

Pipestone, V-7

"Plaskon" 911, IV-47

"Plaskon" Alkyd 411, 420, 422, 440, 440A and 442, IV-49

"Plaskon" Alkyd Special, Electrical Granular, IV-49, 123; V-112, 113

"Plaskon" melamine, IV-22

"Plaskon" Urea, natural and brown, IV-23

"Plasticell," IV-31

"Plast-Iron" and plastic mixtures, IV-43, 44

"Plexiglass," IV-34

"Plicene" Cement, IV-56

"Pliobond" M-190-C, IV-52

"Pliolite" and Pliolite GR, IV-51

"Pliolite" S5, S3, S6B and S6, IV-40

Polaroid Resin C, IV-40

"Polectron" No.24, IV-46

"Policap, " V-16

"Polinel," IV-58

Polyamide resins, IV-23,113; V-8,12,14,82,83,89

Polybutene, IV-59

Polybutyl methacrylate, IV-35

Poly-2-chlorobutadiene-1, 3, IV-53

Polychlorostyrenes, IV-41,42

Polychlorotrifluoroethylene, IV-31, 58, 63, 116; V-10, 102, 103

Polycyclohexyl methacrylate, IV-35

Polycyclostyrene, V-ll

Polydiallyl phthalate, IV-48

Poly-2, 5-dichlorostyrene, IV-40-42, 70

Poly-2, 5-dichlorostyrene + fillers, IV-42-45; V-243

Poly-3, 4-dichlorostyrene, IV-42

Polyesters, IV-46-48,120-123; V-11,12,13,106-111

Polyester resin with "Dacron," V-12, 110

Polyester resin with "Fiberglas," IV-47, 48; V-12, 13, 22, 106, 107, 108

Polyester resin with "Nylon," V-12

Polyester resin with "Orlon," V-12

Polyester resin with phenolic spheres, V-12

Polyether, chlorinated, V-16

Polyethyl methacrylate, IV-35

Polyethylene, IV-27, 28, 70; V-10

Polyethylene (effect of milling), IV-28

Polyethylene DE-3401, IV-27

"Polyglas" D⁺, IV-42

"Polyglas" M, IV-22

"Polyglas" P⁺, IV-41

"Polyglas" S, IV-26

Polyisobutyl methacrylate, IV-35

Polyisobutylene B-100 + Marbon B, IV-28

Polyisobutylene, Run 5047-2, IV-28

Polymethyl methacrylate, IV-34, 70;

Polysiloxane resin, IV-26, 27; V-9

Polystyrene, IV-35-37, 117

Polystyrene, cast in vacuo and cast in air, IV-37

Polystyrene + chlorinated diphenyl, IV-37

Polystyrene, cross-linked, IV-39, 40, 119; V-11, 105

Polystyrene Fibers Q-107, IV-37

Polystyrene + fillers, IV-41; V-10, 239, 240

Polystyrene Foam Q-103, IV-37

Polystyrene, hydrogenated, IV-46

Polystyrene, a-methylstyrene, IV-37, 117

Polytetrafluoroethylene, IV-31-33, 70; V-10,104

Polytrifluorostyrene, V-ll

"Polythene" A-3305, IV-27, 70

Polyvinyl acetal, IV-34

Polyvinyl acetate, IV-33

Polyvinyl alcohol-acetates, IV-33

Polyvinyl butyral, IV-34

Poly-N-vinylcarbazole, IV-46

Polyvinyl chloride 1006, 1018, 1216, 1406, W-174, W-175 and W-176, IV-30

Polyvinyl chloride-acetate, IV-28-31

Polyvinyl chloride-acetate + plasticizer, IV-28, 29

Polyvinyl chlorides, IV-28-31; V-10

Polyvinylcyclohexane, IV-46

Polyvinyl formal, IV-34

Polyvinylidene and vinyl chlorides, IV-31

Poly-a-vinylnaphthalene, IV-46

Poly-2-vinylpyridine, IV-46

Polyvinyl resins, IV-27-46

Polyvinyltoluene, IV-37,117

Poly-p-xylylene, IV-37

Porcelain, wet and dry process, IV-6,100

Porcelain No. 4462, IV-6

Porcelains, IV-6, 94-100; V-2, 3, 5, 21, 40, 59-61

Porous Ceramic AF-497, IV-6, 101

Potassium bromide, IV-1

Potassium chloride, V-1

Potassium dihydrogen phosphate, IV-1,73

"Primol"-D, IV-66

n-Propyl alcohol, IV-62

"Prystal," IV-17

"Pyralin," IV-25

"Pyranol" 1467, 1476 and 1478, IV-63,64

"Pyrex," IV-10

"Pyrotex," V-8

Quartz, fused, IV-11,104; V-6,72,73

"Quinorgo" No. 3000, IV-13

"Quinterra," IV-13

Raytheon 402B, V-3

"Resimene" 803-A, IV-22

"Resinox" 7934, IV-20

"Resinox" 10231, IV-18, 109

"Resinox" 10900, IV-18, 110

Resins, natural, IV-55,56

"Rexolite" 1422, IV-40; V-105

"Rexolite" 2101, V-11

"Rocketon, " V-17

"Royalite" 149-11, M21982-1 and M22190, IV-53

Rubber, butyl (GR-I), IV-52

Rubber, cellular, IV-51

Rubber, cyclized, IV-51,52

Rubber, GR-S (Buna S) and compounds, IV-52

Rubber, Hevea and compounds, IV-51

Rubber, natural, IV-51

Rubber, nitrile, IV-53

Rubber, silicone, IV-54, 55, 126; V-127-129

Rutgers' wallastonite E16, V-4

Rutile, IV-2, 4, 77

S-40 and S-60 resins, IV-39

"Santicizer" 9, IV-15

Sapphire, IV-72; V-1, 26, 27, 28

"Saran" B-115, IV-31

Savereisen Cement No, 1, V-7

"Scotchply" type 1001, V-16

"Scotchply" type 1002, V-22

"Scotchply" XPM-107, V-22 "Scotch" tape No. 39, V-17 Sealing Wax, Red Express, IV-58 Sealing compound, V-17 "Selectron" 5003 + glass, IV-47 "Selectron" 5084 monomer, V-19 "Selectron" 5084 resin, V-13 Selenium, amorphous, IV-13 Selenium, multi-crystalline, IV-1 Shellac, natural XL, IV-55 Shellac, natural Zinfo, pure C garnet and garnet dewaxed, IV-56 "Silastic" 120, 125, 150, 152, 160, 167 and 180, IV-54 "Silastic" 181 and 250, IV-54, 126 "Silastic" X4342, IV-55 "Silastic" 6167, IV-55,126 "Silastic" 6181, X-6734 and 7181, IV-55 Silica, fused 915c, IV-11, 103; V-70,71Silicon dioxide, fused, IV-11, 103; V-70,71Silicon nitrite alloy, V-6,79 Silicone Alloys C-1147 and C-1328, V-9 Silicone fluids DC200 and DC500, IV-66 Silicone fluids DC550 and DC710, IV-67 Silicone fluid DC XF-6620, V-20 Silicone fluids SF96-40, SF96-100 and SF96-1000, IV-67 Silicone glass laminates, IV-26, 27 Silicone grease, V-20 Silicone Molding Compound XM-3,

IV-26

Silicone resin DC996 and DC2101, IV-26 Silicone resin DC301, V-9,94 Silicone laminate DC2105, V-9, 94 Silicone laminate DC2106, V-9, 95 Silicone resins, IV-25-27; V-9 Silicone resins with asbestos, V-9, 96,97 Silicone resins with "Fiberglas," **V**-9, 93-95, 98-101 Silicone rubbers, IV-54, 55, 126; V-127-129 Silicone rubber SE-450, IV-55; V-127 Silicone rubber SE-460, IV-55; V-128 Silicone rubber SE-555, IV-55 Silicone rubber SE-977, IV-55; V-129 Silicone varnish, IV-26; V-18 "Sintox, " V-3 Snow, IV-1 Soap, IV-60 Sodium chloride, IV-2 Sodium chloride, aqueous solutions, IV-61 Soils, IV-14 Steak, IV-60 Steatite bodies, IV-3, 4, 78-87; V-4, 55-57 Steatite Body 7292, IV-4,83 Steatite Type 302, 400, 410 and 452, IV-3,84-87 Sterling M50 varnish on paper, V-18 Strontium titanate, IV-5 Strontium titanate and plastic mixtures, IV-43 Stupakoff 1510, V-3, 51

Stupakoff 1540, V-3, 50

Stupakoff 1542E, V-3

Stupakoff 1542P, V-3, 50

Stupakoff 1550, V-4, 50

"Stycast" HiK, LoK and TPM-3, V-11

"Stypol" 16B monomer, V-19

"Stypol" 16B resin, IV-48,123; V-110

"Stypol" 16C resin, IV-48

"Stypol" 16D resin, IV-48; V-12

"Styraloy" 22, IV-38

"Styramic" No. 18, IV-37

"Styramic" HT, IV-42, 43

Styrene copolymers, crosslinked, IV-39, 40, 119; V-11, 105

Styrene copolymers, linear, IV-38, 39, 118, 119

Styrene dimer, IV-64

Styrene N-100, dry and saturated with water, IV-64

Styrene-acrylonitrile copolymer, IV-38, 53, 118

"Styrofoam" 103.7, IV-37

"Styron" C-176, 411-A, 475, 666 and 671, IV-36

Suet, IV-60

Sulfur, crystalline, IV-2

Sulfur, sublimed, IV-2

"Supramica" 500, V-7, 79

"Tam Ticon" B, BS, C, MC and S, IV-4, 5, 43

"Tam Ticon" T-S, T-L and T-M, IV-4

Taylor Grade GGG, IV-18, 111

Taylor Grade GSC and GSS, IV-27

"Teflon, " IV-31-33, 70; V-24, 104

"Teflon" + calcium fluoride, IV-32; V-10

"Teflon" Laminate GB-112T; IV-31, 32

"Tenite" I 008A H₂, H₄, M, MH, S and S₄, IV-24

"Tenite" II 205A H₂, H₄, MH, MS, S₂, S₄, IV-24

Terphenyl, meta-, nona-, orthoand para-, IV-15

Terphenyls, chlorinated, IV-64

Tetrachloroethylene, IV-62

Tetra alkyd silicate ester, V-19

Thallium bromide, IV-2,75

Thallium bromide-chloride, IV-2,75

Thallium bromide-iodide, IV-2,76

Thallium chloride, V-1

Thallium iodide, IV-2,74

Thermoplastic Composition 1766EX and 3738, IV-58

Thermoplastic Composition 3767A, IV-59

"Thiokol," Type FA, PRI and ST, IV-54

TI Pure R-200, IV-4

Titanate ceramics, IV-5,6

Titania and titanate bodies, IV-4-6, 88-93

Titanium dioxide ceramics, IV-4,5

Titanium dioxide, rutile, IV-2, 4, 77

Titanium dioxide + plastic mixtures, IV-33, 42

Toluene sulfonamides, mixture of ortho- and para- isomers, IV-15

"Transil" Oil 10C, IV-65

Trichlorobenzenes, mixture of isomeric, IV-64

- Trichloronaphthalenes, mixture of isomeric, IV-64
- a-Trinitrotoluene, IV-15
- "Ultron" Wire Compound UL300, UL1004 and UL24001, IV-30
- Union Carbide + Carbon R-63 Varnish, V-18
- Urea-formaldehyde resins, IV-23

Varnished linen tape, V-17 Varnished paper, V-18 Varnished glass cloth, V-18

"Vaseline," IV-65

"Vibron" 140 and 141, IV-40

- "Vinylite" QYNA, VG-5544 and VG-5901, IV-28
- "Vinylite" VG-5904, VYHH, VYNS and VYNW, IV-29
- "Vinylite" VU-1900, IV-29,70
- 2-Vinylpyridine-styrene copolymer, IV-46
- "Vistawax," IV-59

Water, conductivity, IV-61 Wax 3760, IV-59

Wax Compound F-590 and No. 1340, IV-59

Wax S-1167 and S-1184, IV-59

Waxes, IV-56-59; V-16,17

"Wesgo" AL-300, V-4,52

"Wesgo" A1-1009, V-4

Wollastonite, V-4,58

Wood, IV-59

- Zinc ferrite (M.I.T. samples), V-158
- Zinc-magnesium-manganese ferrite (M.I.T. samples), V-141,182
- Zinc-nickel ferrite (M.I.T. samples), V-144-157
- Zirconium porcelain Zi-4, IV-6, 94,95
- Zircons, IV-6, 94, 95; V-5, 59-61